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ACTIVATED SLUDGE. BIO-DISC TREATMENT OF DISTILLERY WASTEWATER

John L. Thomas, et al

American Distilling Company

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ACTIVATED SLUDGE - BIO-DISC TREATMENT OF DISTILLERY WASTEWATER

By

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Project 12060 FLL
Program Element 1BB037

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ABSTRACT

Plant scale evaluation of activated sludge and Bio-Disc (rotating biological contactor) treatment of distillery wastewater has been conducted over a period of more than one year at Pekin, Illinois. The activated sludge process consistently provided in excess of 90 percent removal of BOD_5, even at loadings greater than the treatment plant design levels. Waste flow to the Bio-Disc process had to be reduced from the original design basis of 120,000 gallons per day to 45,000 gallons per day to attain a BOD_5 removal efficiency of 90 percent.

After adjustment of design criteria based on test performance, investment costs for a 530,000 gpd facility were determined to be $809,000 for the activated sludge process and $980,000 for the rotating biological contactor. Annual costs including fixed charges and operating costs were determined to be $188,900 for the activated sludge process and $209,300 for the rotating biological contactor.

The activated sludge process exhibited only a small reduction in BOD_5 removal efficiency when subjected to shock loadings of BOD_5. This same performance could not be demonstrated with the rotating biological contactor configuration used in this facility.

The activated sludge process demonstrated advantages over the rotating biological contactor based on economics, treatment performance, and ability to handle shock loads.

This report was submitted in fulfillment of Project No. 12060 FLL by The American Distilling Company under the partial sponsorship of the Environmental Protection Agency.

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SECTION I - CONCLUSIONS

1. The American Distilling Company wastewater averages 860 mg/l of BOD_5, is extremely variable in strength characteristics, and exhibits a rapid oxygen uptake.
2. Evaluation of long-term records of treatment plant influent quality indicates a correlation of BOD_5:COD as follows:

$$BOD_5 = 0.786\ COD - 35$$

where BOD_5 and COD are expressed in pounds per day.

3. Total BOD_5 in the distillery wastewater is dependent on factors other than bushels of grain mashed. No valid correlation could be established between raw material and wastewater BOD_5 load.
4. The activated sludge process has consistently been successful in removing over 90 percent of the BOD_5 influent to the treatment plant even though such operating parameters as waste volume, waste strength, mixed liquor solids concentrations, and dissolved oxygen levels have varied over wide ranges.
5. The Bio-Disc process has achieved approximately 90 percent BOD_5 removal at flow rates of 40,000 to 50,000 gallons per day when preceded by a detention period in an aerated equalization basin of 10 to 12 hours.
6. Based on variation in the temperature and pH of the waste treated, equalization storage must be provided ahead of the Bio-Disc treatment line. The activated sludge process was not noticeably affected either adversely or beneficially by the equalization pre-treatment.
7. Aeration is required in the Equalization Basin in order to maintain a fresh wastewater amenable to treatment in the Bio-Disc process.
8. The activated sludge process as installed, is capable of handling more flow and organic load than the original design basis.
9. The installed Bio-Disc unit cannot treat the specified wastewater load. Operating results indicate the plant should be rated at 45,000 gpd of flow and 320 pounds per day of BOD_5.

10. Comparisons of both capital costs and annual costs indicate that an activated sludge system is less expensive than a Bio-Disc system for treating a wastewater similar to that from The American Distilling Company plant.
11. Series operation with activated sludge treatment following the Bio-Disc process did not yield any discernable advantage in terms of improved treatment efficiency.

SECTION II - RECOMMENDATIONS

1. An activated sludge system for treating wastewater with characteristics similar to those of The American Distilling Company could be confidently designed on the following basis:

F/M, BOD_5/MLVSS	0.30
MLVSS, mg/l	3,000

2. A Bio-Disc system for treating wastewater with characteristics similar to those of The American Distilling Company should be designed with aerated equalization storage ahead of the biological unit and with the following maximum design loadings:

Hydraulic Loading, gpd/sq ft	1.0
Organic Loading, lb BOD_5/1,000 sq ft/day	7.2

3. Wastes with different characteristics, or subject to another pattern of variation could substantially influence results of investigations reported herein. Therefore, care must be exercised in extrapolating design criteria developed in this research project to other situations.

SECTION III - INTRODUCTION

DISTILLERY PROCESS DESCRIPTION

The research and development project reported herein was conducted entirely at The American Distilling Company plant at Pekin, Illinois. The distillery operation utilizes approximately 12,500 bushels of grain per day as the raw material. Grain use is about 70 percent corn, 20 percent rye, and 10 percent malt. Industrial process operations include mashing, cooking, fermenting, distilling, and by-product recovery for livestock feed production.

The initial process step consists of mixing ground grain with water and cooking to produce a mash. The starch content of this mash is then converted to sugar by a malt. The malted mash is fermented and the sugar content is converted to alcohol. Alcohol is recovered from the mash in a primary distillation column. Distillate from this first column is again distilled in a pot still to refine the product. Mash remaining after distillation is centrifuged and dried to produce a high protein feed.

Process wastewater contains non-recoverable grain particles and by-products such as organic acids, aldehydes, esters, and alcohols. Normal process wastes are increased in flow and strength by the cleaning of grain mixers, cookers, converters, mash coolers, fermenters, stills, centrifuges, and evaporators. A substantial volume of wastewater originates at barometric condensers in the by-product recovery operation.

POLLUTION ABATEMENT BACKGROUND

The American Distilling Company has been systematically working toward solution of water pollution problems at the Pekin plant since 1967. The first investigation, completed in that year, involved a water and wastewater inventory and preparation of a report summarizing the problems and outlining preliminary recommendations for sewer separation and treatment facilities.

Based upon the results of the initial inventory, sources of process and sanitary waste discharges to 20 outfall sewers were identified. A sewer separation program was undertaken to intercept contaminated waste flows entering 11 of these sewers, leaving only clean streams which could be discharged directly back to the Illinois River. Other uncontaminated waters were intercepted before entering the waste sewers and redirected to the clean water sewers. Flows from the sewers containing all of the process and sanitary wastes were collected in an interceptor sewer discharging to a new pumping station which was ultimately incorporated into the treatment plant. Sanitary wastes are those produced by a plant staff of 500 on the day shift and 15 on each of the two other shifts.

High volume, slightly contaminated wastewater discharges from barometric condensers with average BOD_5 content of about 20 mg/l were isolated and combined in a separate trunk sewer for monitoring and direct discharge to the river without treatment. Storm water was handled in a similar manner.

Beginning early in 1968 and continuing for approximately two years, extensive laboratory scale biological studies were conducted by American Distilling personnel. These investigations evaluated the specific characteristics of the wastewater in a biological (activated sludge) treatment process, determined nutrient requirements for treatment, and provided information relative to design of full-scale plant facilities.

In 1970, little technical literature information was available regarding design and operation of full-scale wastewater treatment plants handling distillery process wastes. The laboratory studies completed by The American Distilling Company provided a substantial volume of information on wastewater characteristics but also indicated a need for additional research on this type of waste. A research and development program was, therefore, formulated and submitted to the Environmental Protection Agency

for plant scale evaluation of alternative biological wastewater treatment processes. A grant offer was made to The American Distilling Company on May 27, 1970, and was subsequently accepted.

Design of full-scale treatment facilities was initiated immediately and the plant was completed and placed in operation on September 27, 1971. This report covers the results obtained during the research operational phase of the full-scale treatment facility. Twelve different operating procedures were evaluated including both parallel and series operation of activated sludge and rotating biological contactor processes.

After research operations were terminated, the plant continued to treat wastewater from the industrial operation with discharge of treated effluent to the Illinois River in compliance with current regulatory criteria.

STUDY PURPOSE AND SCOPE

The goals of the demonstration project reported herein are the evaluation, on a plant scale basis of the performance of the rotating biological contactor (interchangeably referred to as Bio-Disc) and activated sludge processes for treating distillery wastewater.

Specific objectives of the project are to determine:

1. Operating characteristics of both types of systems under widely varying conditions of temperature, pH, flow, and organic load.
2. Design parameters for industry-wide wastewater treatment process selection and sizing.
3. Comparative treatment costs for the two types of systems.

SECTION IV - TREATMENT PLANT DESCRIPTION

DESIGN BASIS

The design approach for treatment facilities was directed toward meeting the following two requirements:

1. Reducing waste constituents to a level which would meet effluent criteria regulations.
2. Generation of data to compare the economics and capabilities of the activated sludge and the Bio-Disc processes.

Regulations covering effluent quality as set forth by the Sanitary Water Board (Illinois) indicated an allowable BOD_5 content of 30 mg/l and a suspended solids content of 35 mg/l. These were applicable to the total waste flow including untreated flow from barometric condensers. On this basis, BOD_5 removal of 90 percent for process wastes was planned. This approach is illustrated as follows:

	Process Waste	Barometric Condenser Flows	Total
Flow, gpd	530,000	3,700,000	4,230,000
Raw Waste BOD_5, lb/day	3,200	550	3,750
mg/l	725	18	---
Treated Waste, BOD_5, lb/day	320	550*	870
mg/l	73	18*	25

*No treatment of this waste.

Sampling and gaging data indicated that the daily BOD_5 load and daily flow of process wastes would each exceed the values shown above approximately 20 percent of the time.

Prior to design, an assessment of waste treatability had been made in a series of experiments performed by the technical staff of the American [illegible] Company. Typical data is shown for batch-type tests under Experiment Nos. 20 and 21 reported in Volume III of Laboratory Waste Treatment Experiments, which documents this preliminary laboratory work.

In Experiment No. 20 the effect of aeration time on BOD_5 (unfiltered) removal was checked for the activated sludge process. Five aeration periods were examined ranging from 6 to 24 hours:

EXPERIMENT 20

Run No.	1	2	3	4	5
Aeration Period, hrs.	24	12	10	8	6
Influent BOD_5, mg/l	644	702	563	434	683
Effluent BOD_5, mg/l	17	33	13	8	24
BOD_5 Removal, %	97.4	95.3	97.7	98.2	96.5

Experiment 21 was performed to determine the effect of MLVSS level on BOD_5 removal:

EXPERIMENT 21

Run	1-3	2-3	3-3	4-3
Raw Waste				
BOD_5	655	685	675	680
MLVSS	452	842	1,652	3,326
After 4 hr Aeration				
BOD_5	510	385	176	64
MLVSS	568	1,008	1,742	3,662
BOD_5 Removal, %	22.2	43.0	73.5	90.4
After 8 hr Aeration				
BOD_5	282	120	42	14
MLVSS	--	--	--	--
BOD_5 Removal, %	57.0	82.5	93.8	97.9
After 24 hr Aeration				
BOD_5	38	8	6	5
MLVSS	984	1,604	2,000	3,882
BOD_5 Removal, %	94.2	98.8	99.1	99.3

Notes: 1. All BOD_5 data on filtered samples.
2. All results in mg/l except as noted.

Data from Experiment 21 indicate that a higher MLVSS concentration does increase BOD_5 removal with shorter aeration periods. However, with an aeration period of 24 hours, MLVSS concentrations above 1,500 mg/l do not significantly affect BOD_5 removal.

The above data indicated that treatability requirements (percent BOD_5 removal) could be met for uniform strength waste treated on a laboratory basis with an aeration period of between 4 and 8 hours. Other laboratory tests demonstrated that supplemental nutrient requirements were approximately 1.5 pounds of nitrogen and 0.7 pounds of phosphorus per 100 pounds of BOD_5. Tests on suspended solids production indicated a range of values from 0.16 to 0.35 pounds per pound of BOD_5 in the raw waste.

Design criteria for the activated sludge process were established to recognize variations in pH and temperature. An added requirement was provision of sufficient storage capacity to maintain the process in a viable state over the two-day weekend when it was anticipated that organic loading and flows would be low. A higher solids retention time would also have the latent benefit that endogenous respiration would proceed further and reduce sludge production.

DESIGN LOADINGS

The loadings which were utilized as a design basis for the treatment plant are as follows:

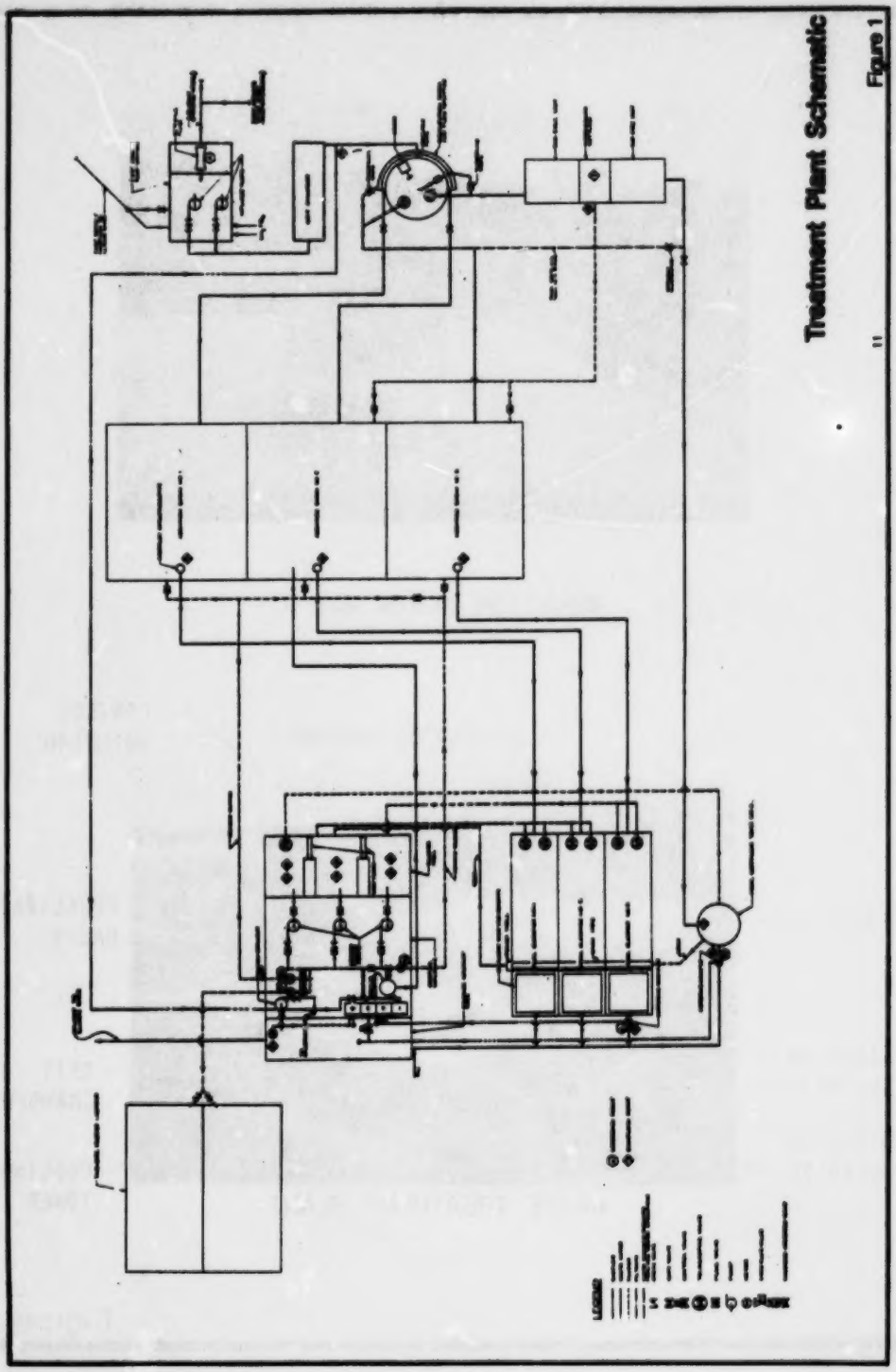
Flow Rate*	530,000 gpd--370 gpm
Peak Flow Rate	1,700,000 gpd--1,200 gpm
BOD_5 Load*	3,200 lb per day
Peak BOD_5 Load	4,400 lb per day
Suspended Solids Load	430 lb per day
Maximum Suspended Solids Load	1,350 lb per day (during clean-up operations)
Nutrient Addition Requirements	5 lb nitrogen per 100 lb BOD_5 1 lb phosphorus per 100 lb BOD_5

*Exceeded 20 percent of time.

PROCESS DESCRIPTION

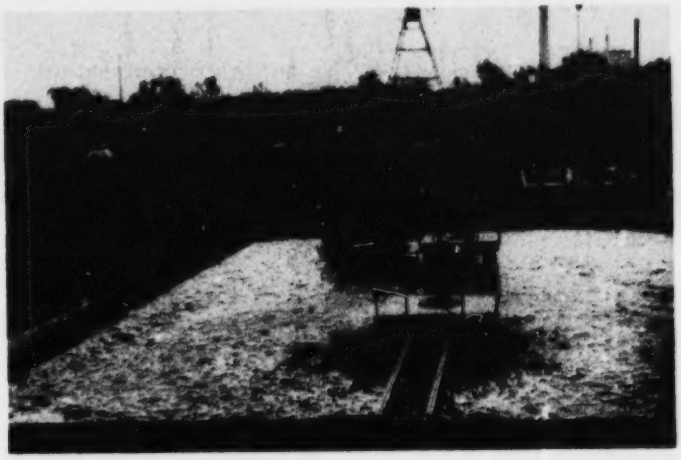
Figure 1 is a plant flow schematic which illustrates the relationships between the various treatment unit processes. Two photographs, showing plant facilities are included on Figure 2. Following is an outline description of the process flow pattern.

1. Waste is received at the pump station, metered, and discharged to treatment facilities.
2. Nutrients, including nitrogen as a water solution of anhydrous ammonia and phosphorus as a solution of triple superphosphate, are mixed with the waste in the wet well.
3. Wastewater flows to a grit chamber where large particulate matter is removed.
4. Four secondary treatment lines are utilized including three for activated sludge treatment (Lines 1, 2, and 3) and one Bio-Disc process (Line 4). Lines 3 and 4 are used to generate research data with Lines 1 and 2 treating flow in excess of that required by Lines 3 and 4 for test conditions.
5. Flow to the Bio-Disc passes through an equalization basin to minimize short-term peak variations in pH, temperature, and organic load. This unit also functions as a flow splitter to divide waste flow among the four process treatment lines in the desired proportion.
6. Influent to Aeration Basin No. 3 can be taken from the Equalization Basin or directly from the grit chamber.
7. Piping is provided so that flow can be directed through the Bio-Disc and Aeration Basin No. 3 in series.
8. Secondary clarification is provided for all lines. Sludge can be recirculated to aeration basins or pumped to the sludge disposal area.



Treatment Plant Schematic

Figure 1



AERATION BASIN NO. 3

WASTE TREATMENT PLANT

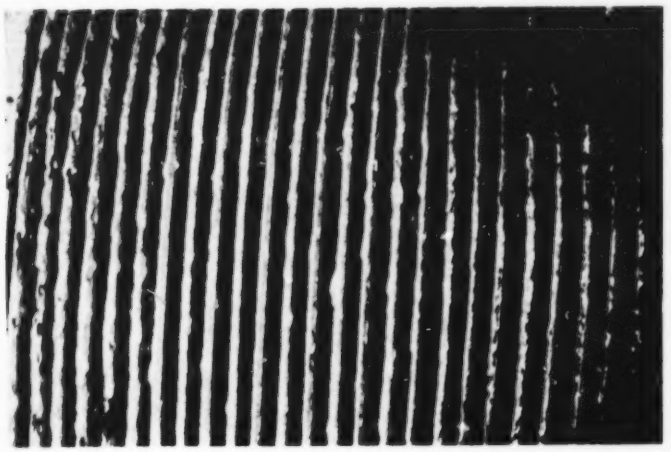
Figure 2

9. Waste sludge is pumped to lagoons.
10. Total plant effluent is chlorinated prior to discharge to the Illinois River.

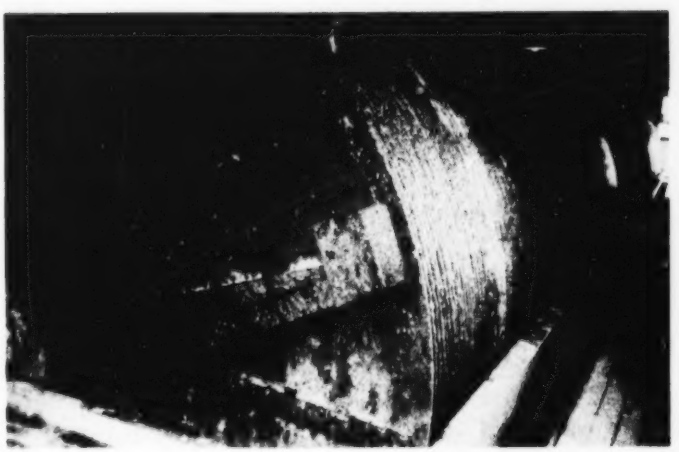
In the basic parallel flow sequence, as contemplated in the initial plant design, a constant 25 percent of the plant design waste flow (133,000 gpd) would be directed to the Bio-Disc unit and another 25 percent routed to Aeration Basin No. 3. The balance of the waste flow would be treated in Aeration Basin Nos. 1 and 2.

The Bio-Disc unit consists of a series of closely spaced discs mounted on a horizontal shaft. Discs are submerged in the wastewater to just below the shaft level in a tank with the bottom formed in a cylindrical shape slightly larger than the discs. Rotation of the shaft alternately exposes disc surface area to the wastewater and to the atmosphere. The discs thus serve both as media for growth of a biological slime and as an aeration device. Intermediate settling is provided between the second and third stages of the six-stage Bio-Disc. Sludge removed at this point is normally discharged to Aeration Basin No. 2 for further stabilization. Flow from the final stage of the Bio-Disc is by gravity to a final clarifier. Photographs of the Bio-Disc are shown on Figures 3 and 4.

Three identically sized aeration basins operating as complete mix activated sludge units are provided for contact between the active microorganisms and the waste materials. A photograph of Aeration Basin No. 3 is shown on Figure 2. A separate final clarifier is provided for each aeration basin. Sufficient underflow from the final clarifiers is returned to the aeration basins to maintain the desired mixed liquor suspended solids content. Provision is made for up to 100 percent sludge return. The remaining sludge is wasted. It is possible to return the sludge from Final Clarifier No. 3 to Aeration Basin No. 3 independent of the operation of other basins and clarifiers.

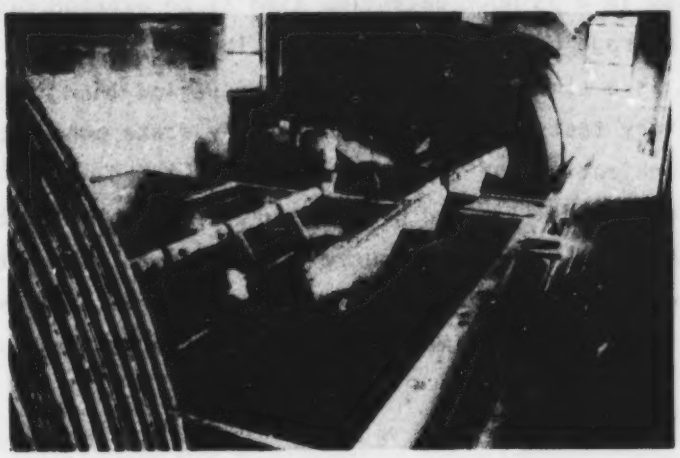


BIO-DISC BIOLOGICAL MASS



BIO-DISC

Figure 3



INTERMEDIATE BIO-DISC CLARIFIER

Figure 4

DESIGN CRITERIA

The activated sludge aeration basins and associated final clarifiers were designed to provide 90 percent reduction of BOD_5. Aeration basins were sized for a solids retention time of approximately 30 days at average flow rates. This resulted in a 33-hour detention time at an average flow of 177,000 gpd and an average organic loading of 33 lb BOD_5 per 1,000 cubic feet per day. This is a somewhat longer detention period than requirements indicated by laboratory tests performed under steady state conditions. However, additional objectives of the design as established were to achieve some measure of aerobic digestion and provide sufficient aeration basin volume to dampen out the effect of the large hourly variations in wastewater flow, temperature, pH, and strength. Maintaining a viable active mass over week-end low load periods was particularly important. Data on variations experienced are discussed later herein.

The design criteria necessary to adapt the Bio-Disc to this waste were more difficult to project. This equipment with a multi-stage arrangement provides a closer approach to a plug-flow biological process with each of the 6 stages serving as a completely mixed reactor. It was reasoned that some equalization would be required to minimize variation in influent waste temperature and pH. It was reported that temperatures in excess of 85 F and pH values outside the range of 6.0 to 8.5 would impair process performance. Therefore, an equalization basin with a detention time of about 9 hours at a flow of 120,000 gpd was incorporated in the treatment cycle. The Bio-Disc system was specified to provide 90 percent reduction of BOD_5 and suspended solids at an average flow rate of 120,000 gpd and a BOD_5 loading of 800 lb per day. The hydraulic capacity of the Bio-Disc is somewhat less than 133,000 gpd (25 percent of total plant capacity). This occurred because plant design flow criteria were increased based on added measurement data available subsequent to Bio-Disc purchase. Specifications set forth performance requirements. The manufacturer was required to establish detail design criteria. Equipment sizing resulted in an average

organic loading of 17.8 lb BOD_5 per 1,000 sq ft of biological surface area and an average hydraulic loading of 2.67 gpd per sq ft. The design organic loading on the first stage is 69 lb of BOD_5 per 1,000 sq ft of biological surface.

A summary of design criteria and significant features of each of the major units in the treatment system follows:

Raw Waste Pumps

1. Two identical 2-speed vertical centrifugal pumps provided.
2. Characteristics:

No. of Pumps Running	Speed (rpm)	Flow (gpm)	Head (ft)
1	1,150	1,200	42
1	860	400	33.5
2	860	580	35.5

Grit Chamber

1. Rectangular horizontal flow type with mechanical grit collection equipment.
2. Design basis: horizontal velocity range, 0.75 to 1.20 feet per second; overflow rate - 40,000 gpd/sq ft.

Nitrogen Addition

1. Equipment: ammoniator to feed anhydrous ammonia in aqueous solution.
2. Maximum feed rate: 240 pounds per day as N.

Phosphorus Addition

1. Equipment: chemical solution tank with mixer to dissolve fertilizer grade triple superphosphate pellets; variable speed chemical metering pump to feed PO_4 solution.
2. Maximum feed rate: 71 pounds per day as P.

Equalization Basin

1. Volume: 44,200 gallons.
2. Detention time: 8.9 hours at 120,000 gpd.
   2.0 hours at 530,000 gpd.

Bio-Disc

1. Number of stages: 6.
2. Discs:
   - Number: 154 in first two stages.
     144 in other four stages.
     298 total.
   - Size: 9.84 ft (3 meters) in diameter.
     0.5 inch (13 mm) in thickness.
     1.35 inches (34 mm) spacing.
   - Material: Expanded molded polystyrene.
3. Biological surface: 45,000 sq ft.
4. Hydraulic loading:

Flow (gpd)	Loading (gpd/sq ft)
120,000 (design)	2.67
530,000 (maximum)	11.8

5. Organic loading (design basis):
   - Total: 800 lb BOD_5 per day.
   - Average: 17.8 lb BOD_5 per 1,000 sq ft per day.
   - First Stage: 69.0 lb BOD_5 per 1,000 sq ft per day.

Final Clarifier Nos. 1, 2, and 3

1. Hydraulic loading: 177,000 gpd each, 404 gpd per sq ft.
2. Normal detention time: 7.9 hours.

Final Clarifier No. 4

1. Hydraulic loading: 132,500 gpd, 580 gpd per sq ft.
2. Normal detention time: 3 hours.

Aeration Basins

1. Three equal size units provided.
2. Hydraulic loading: 177,000 gpd each (average); 567,000 gpd each (peak flow rate).
3. Volume: 244,000 gallons each.
4. Detention time: 33 hours at average flow rate.
5. Average organic loading: 1,070 pounds BOD_5 per day each; 33 pounds BOD_5 per 1,000 cu ft per day.

Aerators

1. Fixed pier surface aerators, two provided per basin.
2. Design specifications:

   Size (each): 20 HP

   Oxygen transfer: 3.2 lb/hp-hr at 20 C in clean water.

   2.0 lb/hp-hr at 10 C in mixed liquor.

   $\alpha = 0.8$

   $\beta = 0.9$

Sludge Pumps

1. Three horizontal centrifugal pumps provided.
2. Capacity: 200 gpm each at 23 feet head.
3. Return sludge capability: 0 to 100 percent of design average flow.

SECTION V - WASTEWATER CHARACTERISTICS

GENERAL

Wastes generated by The American Distilling Company process operations are typical of many industrial installations. Design bases and wastewater treatment operational conditions are sensitive to numerous factors including the following:

1. Substantial hour to hour, day to day, and longer term fluctuations in total organic wastewater loads. An operation such as mashing may occur two, three, or four days per week. Distilling may be performed on other days while normal operation will, at times, include both processes. Equipment cleaning also results in periodic additions to the normal process waste streams. Fermenter washing and pot still cleanout are typical of such operations.
2. Variations occur in pH, temperature, and flow volume. The pH of the waste is increased periodically by the presence of alkaline cleaning chemicals and has been observed to vary from a low of 5 to as high as 13. Large flows of condensate during periods of evaporator operation significantly increase the total process waste temperature with extremes of 50 F and 150 F experienced.
3. Reduced industrial processing on weekends results in extended periods of low feed to biological systems.

Sampling, gaging, and quality analyses conducted as part of the initial survey study indicated substantial flow, BOD, and suspended solids variations. Upon completion of the sewer separation program, a continuous sampler was installed on the total combined process waste stream. Composite sample data further substantiated the variation of the wastewater characteristics and ultimately provided the basis for design loadings to the wastewater treatment facilities.

Compilation of data on raw waste was continued during the period of treatment plant evaluation. This not only permitted determination of plant performance, but also served as a basis for a more complete analysis of of raw waste characteristics.

TOTAL ORGANIC LOAD

Treatment plant design was based on the original wastewater survey data and on an anticipated grain mashing schedule of five days per week. Design parameters were: a daily BOD_5 load of 3,200 pounds exceeded 20 percent of the time; and an average flow of 530,000 gallons exceeded 20 percent of the time. The design load of 3,200 pounds of BOD_5 per day and a flow of 530,000 gpd results in a BOD_5 concentration of about 725 mg/l.

An attempt was made to correlate wastewater BOD_5 with bushels of grain mashed. Because of changes in distillery operations from day to day, the relationship was investigated for one week periods rather than single days. Such one week periods include a normal recurring cycle of operations.

Data comparing bushels of grain mashed with total weekly wastewater BOD_5 are shown on Figure 5. Two curves are also presented with equations as follows:

Curve A: $BOD = 0.256\ B$

Curve B: $BOD = 7{,}982 + 0.177\ B$

Where

BOD = Weekly raw waste BOD_5, lb.

B = Grain mashed weekly, bushels.

The equation for Curve A is derived from the design bases of 3,200 pounds of BOD_5 and a daily grain mash of 12,500 bushels. This approach assumes that BOD_5 produced is a direct function of grain mashed; however, it must be recognized that during the study period there was no week when the grain mashed averaged 12,500 bushels per day for all seven days.

Relation Of Raw Waste BOD_5 To Grain Mashed

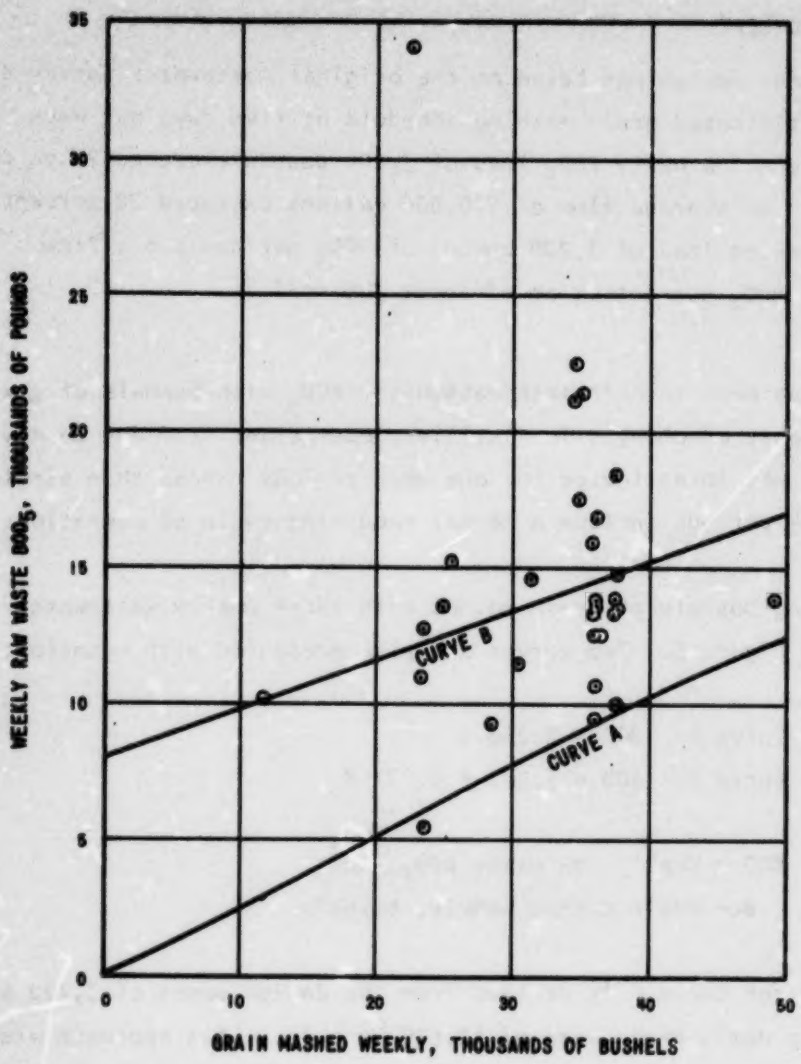


Figure 5

The equation for Curve B is a least squares fit of actual data to establish a linear relationship. It is concluded from the examination of data and Curve B that BOD_5 cannot relate directly to bushels of grain mashed. Detailed investigations to establish causes for the lack of correlation between raw material and waste load were not within the scope of the study reported herein. However, probable factors include lack of consistency in the amount of material wasted during cleanup operation, occasional dumps of partially processed material, and similar items.

Figure 6 graphically depicts the frequency of daily BOD_5 load occurrence. For the period of November 1, 1971, through October 1, 1972, the daily BOD_5 load exceeded 3,200 pounds 24 percent of the time. During almost all of this time, grain was being mashed only three days per week; there were no weeks when grain was mashed five days, and only one when mashing occurred four days.

Therefore, the treatment plant has been operating at or above the design BOD_5 load while the average raw material flow to the distillery has been only about 60 percent of design levels. If grain mashing were performed five days each week at a rate of 12,500 bushels per day, it is doubtful that daily BOD_5 loading would be any greater than currently experienced.

There have been several shock BOD_5 loads to the plant. Two were particularly large; almost 7,600 pounds on March 13, 1972, and over 31,000 pounds on July 12, 1972. The reactions of the activated sludge and Bio-Disc treatment facilities to such loads are discussed in later sections of this report.

BOD_5 Load Frequency
Treatment Plant Influent

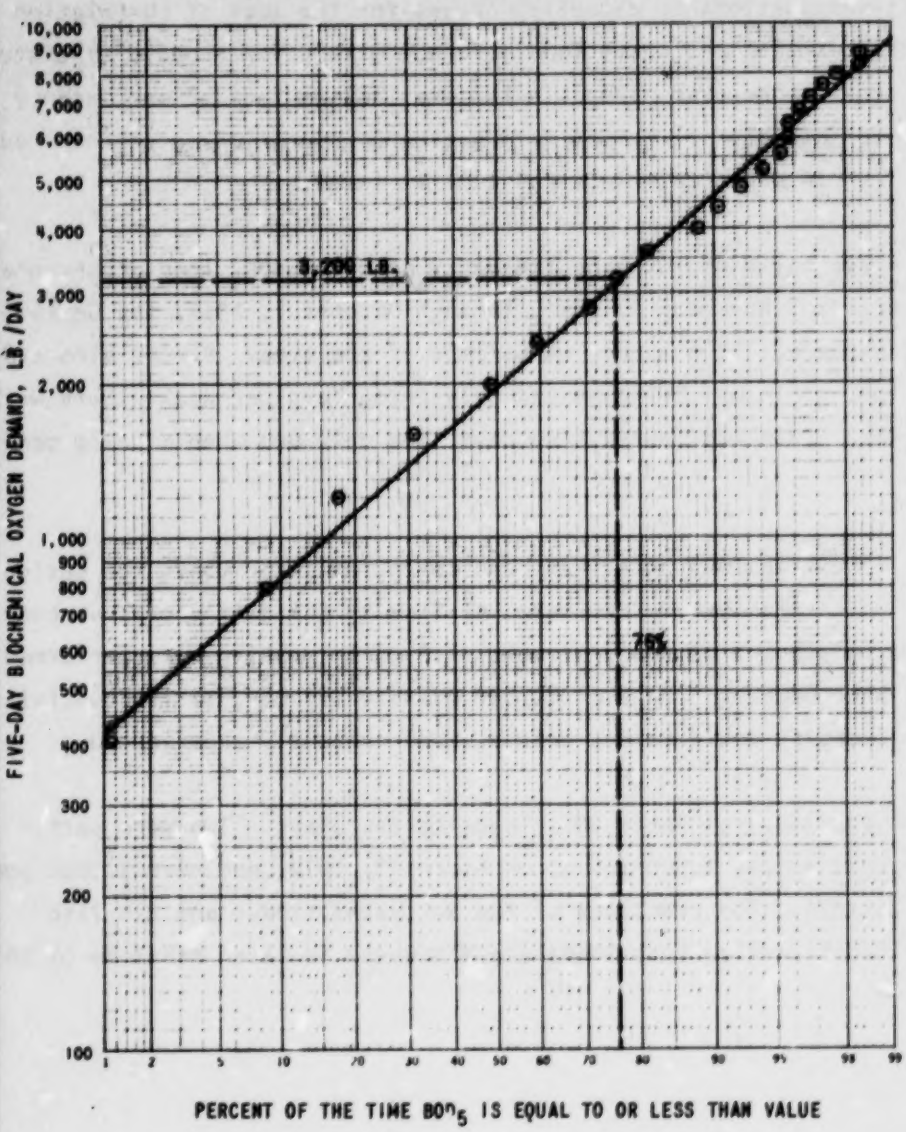


Figure 6

Typical hourly variation of raw waste BOD_5 is shown below:

TYPICAL BOD_5 HOURLY VARIATION

Time	Monday BOD_5 (mg/l)	Thursday BOD_5 (mg/l)
9 AM	560	1,140
10 AM	560	790
11 AM	560	790
12 PM	560	790
1 PM	560	1,130
2 PM	560	790
3 PM	560	790
4 PM	560	790
5 PM	560	790
6 PM	1,180	790
7 PM	920	790
8 PM	560	334
9 PM	560	334
10 PM	560	800
11 PM	1,160	334
12 AM	560	334
1 AM	1,150	334
2 AM	560	334
3 AM	560	334
4 AM	560	334
5 AM	560	1,140
6 AM	560	1,100
7 AM	560	527
8 AM	560	527

All results presented herein are based on a five-day operational week from Monday through Friday unless otherwise noted. Weekend flows and BOD_5 loads to the treatment plant have not been subjected to detailed study. However,

a variation similar to that which occurs in the weekday loads has also been observed in the weekend flows. During the period of March 4, 1972, through July 16, 1972, data for eighteen weekends was analyzed. BOD_5 loads for the two-day period varied from 395 to 5,925 pounds. During the period of November 6, 1971, through July 15, 1972, flows for reported two-day weekends ranged from 102,500 gallons to 703,000 gallons. Daily BOD_5 load and flow during weekends averaged 25 to 50 percent of the previous week daily values.

BOD_5:COD RELATIONSHIP

The magnitude of the BOD_5 load and the pattern of variation must be known to control such operating factors as:

1. Nutrient addition.
2. F/M.
3. Aerator operating schedule.

The BOD_5 test takes five days for completion. If the sample were a 24-hour composite, a period of six days can elapse between the receipt of the BOD_5 load for treatment and the determination of its magnitude. Also, the BOD_5 test is recognized by various authorities as being subject to a great deal of error. Precision and accuracy are both rather low, particularly for high concentrations, where slight errors in dilution or seeding can be multiplied by large factors.

At some waste treatment plants, the BOD_5 concentration or weight per day is relatively constant or varies with some regular pattern. At The American Distilling Company plant, no such consistency or pattern has been observed. Without any prior information as to magnitude of the likely BOD_5 load for a given day, the plant operator must set nutrient feed rates at arbitrarily high levels so that enough nitrogen and phosphorus will be available during times of high loads. This has led to an unnecessarily high concentration of nitrogen and phosphorus in the effluent during days of low loads.

A correlation between influent BOD_5 and COD was sought in an effort to correct this condition. The COD test is run in a few hours, and is more precise and accurate than the BOD_5 determinations. If a reasonable correlation could be developed between BOD_5 and COD, then a treatment plant operator would be able to utilize a COD test on a grab or short-term composite sample of influent waste to obtain an idea of the magnitude of load coming into the treatment plant. A BOD_5:COD relationship for the raw waste entering Aeration Basin No. 3 is shown on Figure 7.

Fitted by a computer analysis to a linear equation form using the method of least squares, the BOD_5:COD relationship in terms of pounds per day shown on Figure 4 is as follows:

$$BOD_5 = 0.786\ COD - 35$$

OTHER PARAMETERS

Typical hourly variations in temperature, pH, and flow of raw waste are shown on Figures 8, 9, and 10.

METERING, SAMPLING, AND TESTING

Points of routine metering and sampling within the wastewater treatment process are shown on Figure 1 and are summarized on the following page. The various flow streams are tabulated, along with the type of metering element and the data the element generated.

COD And Corresponding BOD_5 Activated Sludge Process Influent

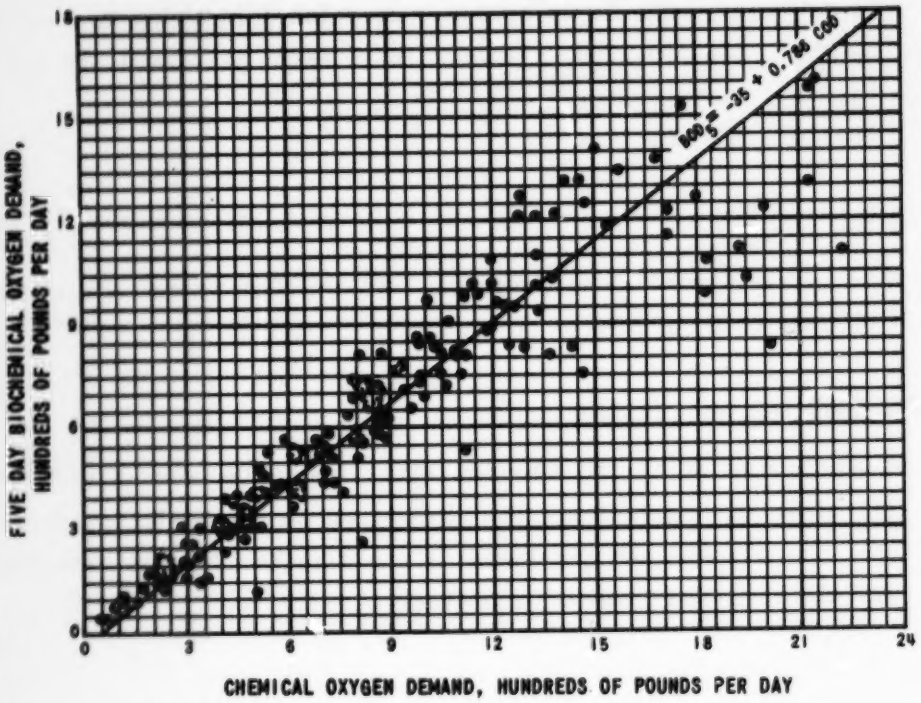


Figure 7

Temperature Variation
Treatment Plant Influent

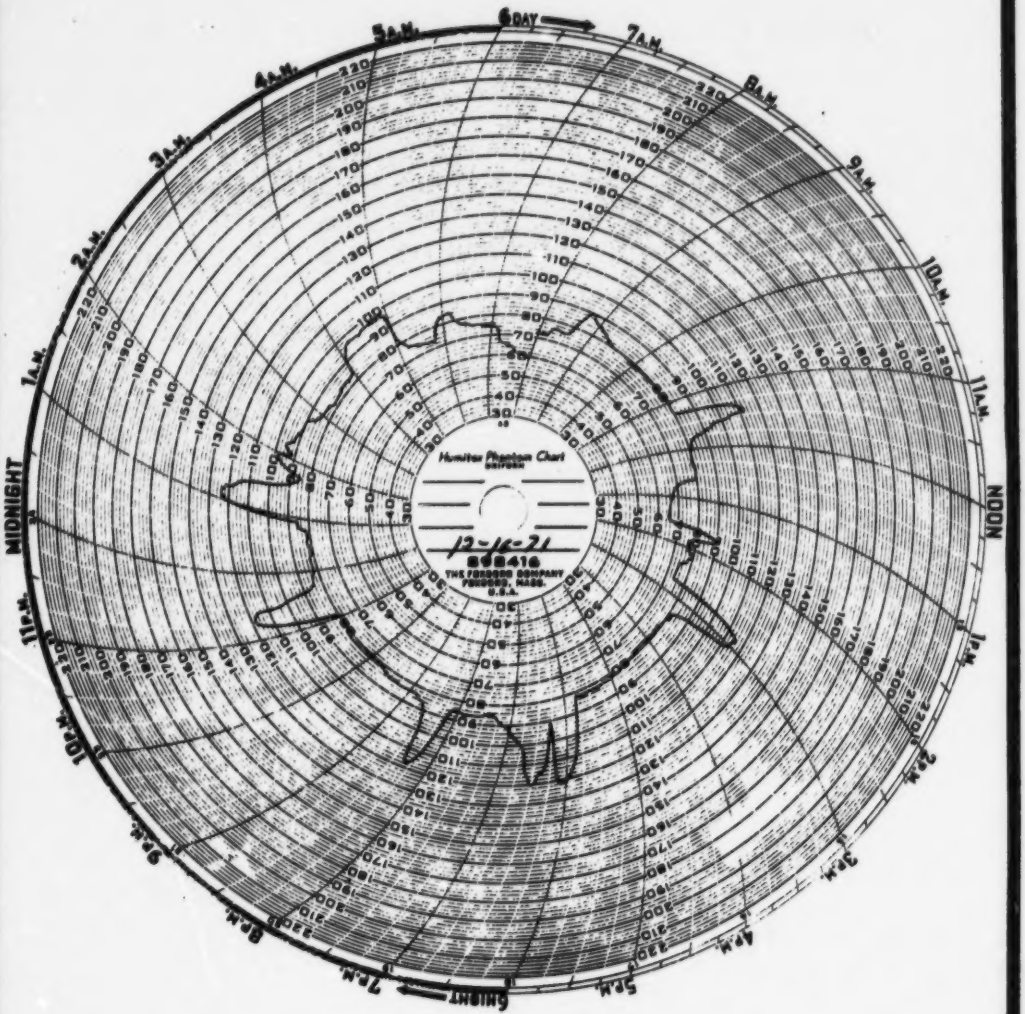


Figure 8

pH Variation
Treatment Plant Influent

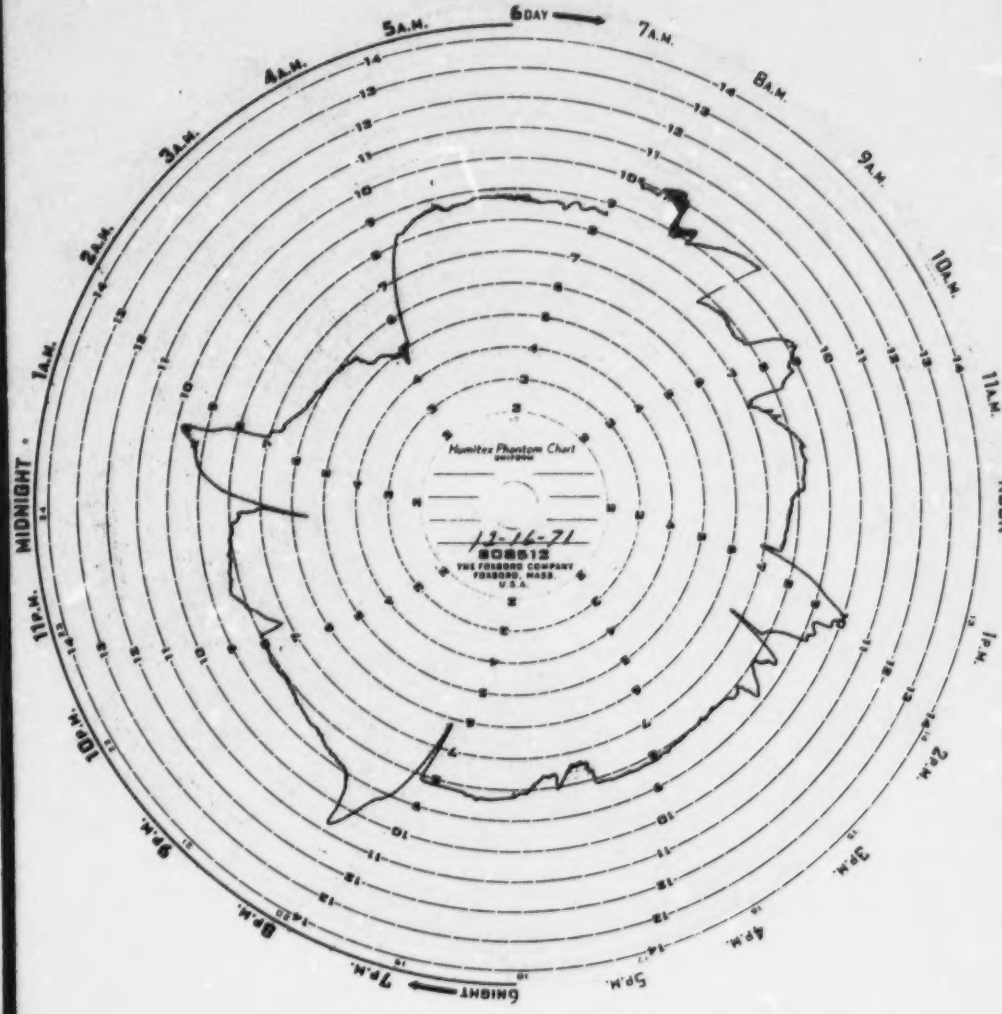


Figure 9

Flow Variation
Treatment Plant Influent

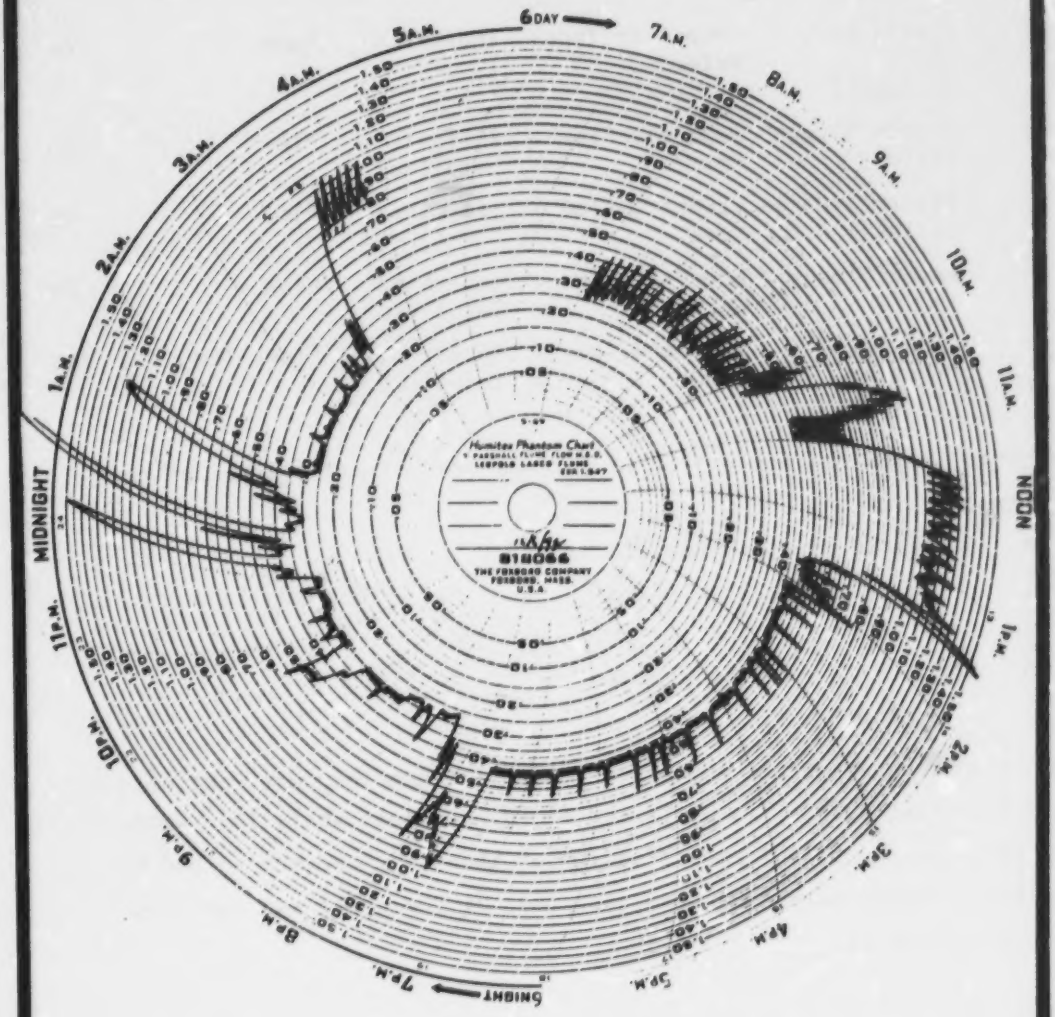


Figure 10

Sampling Point	Flow Stream	Primary Metering Element	Flow Data	Parameters Continually Monitored	Composite Samples Collected
A	Raw Waste	Palmer-Bowlus Flume	Recorded	pH, Temp. Flow	Yes
B	Clarifier 4 (Bio-Disc effluent)	Propeller Type Meter	Indicated	None	Yes
C	Clarifier 3 (A.S. effluent)	Propeller Type Meter	Indicated	None	Yes
D	Return Sludge Basin 3	Magnetic Flow Meter	Indicated, Totalized	Flow	No
E	Return Sludge Basins 1 & 2	Magnetic Flow Meter	Indicated	Flow	No
F	Waste Sludge	Magnetic Flow Meter	Indicated, Totalized	Flow	No
G	Combined Plant Effluent	Palmer-Bowlus Flume	Recorded, Totalized	Flow, Temp.	Yes

Other sampling points where flow is not measured directly include the following:

H Activated sludge mixed liquor.

I Third stage Bio-Disc effluent.

J Clarifier No. 4 influent.

S Effluent of Equalization Basin.

As shown on the preceding tabulation, composite samples were routinely collected from four points (A, B, C, and G) for complete analysis. Temperatures were continuously recorded at two of these four points (A and G) while field checks were made, one each day, at the other two sampling locations (B and C).

Other tests were made on grab samples or manually composited samples, as required. The schedule and frequency of tests is shown in Table 1.

Table 1

WASTEWATER TESTING PROGRAM

Sampling Point	Number of Tests Per Week										
	A	B	C	D	E	F	G	H	I	J	K
Biochemical Oxygen Demand	2	2	2	-	-	-	2	-	1	1	-
Soluble BOD	2	2	2	-	-	-	-	-	-	-	-
Chemical Oxygen Demand	5	5	5	-	-	-	1	-	1	1	-
Soluble COD	5	5	5	-	-	-	-	-	-	-	-
Total Suspended Solids	5	5	5	5	5	5	2	5	1	1	5
Volatile Suspended Solids	5	5	5	5	5	5	-	5	1	1	5
Soluble Solids	5	5	5	-	-	-	5	5	-	-	-
pH	R*	5	5	-	-	-	5	5	1	1	-
Temperature	R	5	5	-	-	-	R	5	1	1	-
Dissolved Oxygen	-	1	1	-	-	-	-	5	1	1	-
Nitrite-Nitrate Nitrogen	2	2	2	-	-	-	1	-	-	-	-
Kjeldahl Nitrogen	2	2	2	-	-	-	1	-	-	-	-
Ammonia Nitrogen	2	2	2	-	-	-	1	-	-	-	-
Total Phosphorus	2	2	2	-	-	-	1	-	-	-	-
Chlorine	-	-	-	-	-	-	5	-	-	-	-

*R--Continuous recording.

All samples were analyzed at The American Distilling Company laboratory, by plant personnel. All analyses were conducted in accordance with the 12th edition of Standard Methods for the Examination of Water and Wastewaters.

SECTION VI - OPERATIONAL DATA AND EVALUATION

OPERATIONAL CHRONOLOGY AND RESULTS

To achieve the stated objectives of the research project, the study period was divided into a series of stages, each with specific desired operational characteristics. Plant operation was initiated on September 17, 1972. During the period of study from September 27, 1971, to December 24, 1972, twelve operational stages were completed.

To analyze system operation a seven point approach was contemplated:

1. Start-up of facilities with growth and acclimation of the bio-mass to establish a basic plant operational mode necessary to achieve 90 percent removal of BOD_5.
2. At a constant flow of 133,000 gpd through the activated sludge process, determine the effect of varying MLSS and/or MLVSS.
3. Vary the flow through the Bio-Disc and activated sludge processes to determine effect of BOD_5 removal. Hold MLSS concentration in aeration basin at previously determined optimum level.
4. Operate the Bio-Disc and activated sludge processes at optimum flow level to obtain 90 percent BOD_5 removal. Maintain MLSS at optimum level.
5. Vary the detention time of waste in Equalization Basin to determine any effects of pH and temperature on the biological process in either the Bio-Disc or activated sludge system.
6. Operate the Bio-Disc and activated sludge processes in series at several flow levels to determine performance with this operating mode.
7. If time permits, vary nutrient levels to establish optimum levels.

Detail planning of operating parameters for individual stages changed throughout the investigation as results of performance of previous stages were evaluated. A summary of planned and actual operating conditions provides an overview of conditions prior to a detailed discussion of each stage. This data is shown in Tables 2 and 3.

TABLE 2

BIO-DISC OPERATING PATTERN

Stage	Flow (1,000 gpd) Planned	Actual (Average)
1	--	57
2	60	63
3	60	69
3A	45	45
4	45	49
5	45	45
6	45	48
7	45	45
8	90	71
9	130	114
10	65	55
11	72	65
12	265	224

After an initial attempt in Stage 1 to treat waste with the Bio-Disc at a flow rate of 133,000 gpd without acceptable performance, the rate was decreased to 60,000 gpd then to 45,000 gpd. Aeration of the Equalization Basin was initiated at the start of Stage 7. In subsequent stages flow was increased to determine if such aeration would provide better performance. The high flow rate in Stage 12 was established to determine performance of series operation with the activated sludge process.

For the activated sludge process, it was planned to maintain a constant flow through Stage 5 and increase the MLSS (and MLVSS) to determine optimum concentration. In subsequent stages, the flow was first decreased then later increased to determine the effect on process performance. At higher flows it was anticipated that BOD_5 removal would decrease to the 90 percent level.

TABLE 3

ACTIVATED SLUDGE OPERATING PATTERN

Stage	Flow (1,000 gpd) Planned	Flow (1,000 gpd) Actual (Average)	MLSS (mg/l) Planned	MLSS (mg/l) Actual (Average)	MLVSS (mg/l) Actual (Average)
1	--	92	--	--	2,470
2	133	135	1,250	--	1,471
3	133	156	2,500	2,500	2,187
3A	133	123	3,500	2,198	1,929
4	133	114	3,500	3,615	3,060
5	133	148	4,500	4,294	3,610
6	80	79	4,500	3,661	3,105
7	45	50	4,000	3,958	3,350
8	90	78	4,500	4,208	3,649
9	130	118	4,500	4,237	3,488
10	185	170	4,000	4,860	4,053
11	212	195	4,000	4,025	3,475
12	265	224	4,000	--	2,721

Stage 1 (September 27, 1971, to February 6, 1972 - 19 weeks)

The purpose of this stage was to establish an acclimated biological environment for both the activated sludge and Bio-Disc processes. Seeding was performed with activated sludge containing a suspended solids content of 10,500 mg/l obtained from the Greater Peoria Sanitary District. The aeration basins received 1,950 gallons and the Bio-Disc received 650 gallons of this material. To aid in acclimation, flow was sent to treatment facilities for only 8 to 15 hours per day for the first two weeks. In addition, it was planned that this stage would provide an opportunity to determine and to correct any start-up mechanical or operating problems.

Initial planning contemplated a flow of 133,000 gpd (25 percent of total plant design flow) to the activated sludge process (Aeration Basin No. 3) and the same flow to the Bio-Disc. Flows to both processes were routed through the Equalization Basin on the basis that both should receive waste with the same characteristics.

By early November, it became apparent that the Bio-Disc could not treat waste flows of this magnitude and achieve 90 percent BOD_5 removal without some modifications to operating conditions. Flows to the unit were reduced to about 50,000 gpd after November 14 and various problems in the operating environment were considered. These included the following:

1. pH variation.
2. Temperature variation.
3. Zero dissolved oxygen in waste from Equalization Basin.

The pH of the incoming raw waste varied from less than 5.0 to greater than 10.0. This was measured by a continuous recorder. The ability of the Equalization Basin to minimize this range had not been established. Therefore, grab samples of waste entering the Bio-Disc were checked periodically during December, 1971. Although a variation from 6.4 to 9.9 was noted by test, it was assumed that a wider range probably had been experienced. Likewise, raw waste temperature exceeded 140 F at times, but intermittent temperature readings at the Bio-Disc did not exceed 91 F.

Although the dissolved oxygen of the waste entering the Bio-Disc was zero, it was assumed at that time that high pH and high temperature were the major factors responsible for poor performance. On January 11, the flow pattern was changed to reduce the effect of sudden peaks in raw waste temperature and pH. Flow to the activated sludge process was routed to bypass the Equalization Basin. Only flow to the Bio-Disc was routed through the Equalization Basin. This effectively increased the equalization period a

therefore, should have minimized pH and temperature reduction. However, this longer detention period produced a septic waste in the Equalization Basin. BOD_5 removal rates through the Bio-Disc process improved after January 11 (61.6 percent during the week of January 10 to 90.2 percent during the week of January 31). On January 31, to alleviate the septic waste problem, the detention time of the basin was again shortened by routing part of the flow to the activated sludge process through the Equalization Basin. It was not possible to determine the division of flow but it was estimated that approximately one-half the flow through the Equalization Basin went to the Bio-Disc. The Equalization Basin was cleaned in early February, but septic conditions quickly reappeared. Contents removed were black solids including some grain particles and carbon.

The activated sludge process, represented by Aeration Basin No. 3 and Final Clarifier No. 3, displayed the capability of removing greater than 90 percent of the influent BOD_5 during this stage. Operations were hampered by recurring difficulties with the stationary aerators.

The following is a summary discussion of start-up adjustments and operational problems which were recognized and dealt with during the early phases of the investigations:

Surface Aerators - The pier-mounted surface aerators required numerous mechanical modifications. These units exhibited excessive vibrations due to lack of dynamic balance. This caused mechanical failure. In November, the pier-mounted aerators were replaced by temporary floating units while repairs were made to the original equipment. The pier-mounted aerators were all operating again by February 4.

Nutrient Addition - Nitrogen and phosphorus were added to the wastewater to provide necessary nutrients for biological growth. The planned nitrogen and phosphorus additions were 5 percent and 1 percent of the raw wastewater BOD_5 content, respectively. To meet this requirement, anhydrous ammonia was injected as a water solution to provide nitrogen and triple superphosphate was added to provide phosphorus.

Both nutrient supply systems developed problems with plugging of supply piping. This was solved in the phosphate system by:

1. Mixer modification in the supply tank to provide better dispersion of the sparingly soluble triple superphosphate.
2. Screening of the phosphate suspension prior to pumping (30 mesh screen).
3. Use of supplemental carriage water (well water) to dilute the phosphate suspension.

The nitrogen system originally relied upon untreated well water as a carrier of the ammonia nitrogen to the pump station wet well. The high pH of the ammonia solution resulted in precipitation of calcium carbonate and possibly some magnesium hydroxide. Scale formations completely plugged the ejector in only a few hours. This problem was minimized by substituting mixed liquor from Aeration Basin No. 2 for the well water as the carriage liquid.

Grit Removal - The amount of material removed in the grit chamber far surpassed original design estimates. It was anticipated that the quantity of grit including inorganic materials such as sand and cinders would be only a few cubic feet per day. However, presence of other materials such as whole and broken grain kernels increased the amount of readily settleable materials. Carryover of some of this material settled in the flow splitter channels of the Equalization Basin. Therefore, velocity in the grit chamber was reduced approximately 75 percent to 0.25 to 0.30 feet per second by adjustment of weir level. Resulting material removed in the grit chamber increased to a level of 2 to 3 cubic yards per week. This necessitated construction of a chute to transport the materials to the ground to replace the original receiving container. Some freezing of the moist solids in the grit chute has been experienced.

Flow Rates - With a varying raw waste influent flow, adequate wet well equalizing storage must be available to maintain a minimum continuous flow to treatment facilities. In this instance equalizing storage with one pump operation is less than 1,000 gallons. Since the wet well was constructed prior to the gaging period which established flow characteristics, sufficient equalizing capacity has not been available to maintain a continuous flow. Therefore, as the inflow pattern changes flow distribution to the individual treatment lines also changes. However, a reasonably constant flow during the Monday thru Thursday period of the operating week has been maintained by pump throttling. On Fridays, flow is lower and more frequent "off" periods are experienced in pump operations. This results in a lower daily flow to treatment facilities under study and accounts for a significant part of recorded variation. It should be noted that the Equalization Basin is arranged only for waste quality equalization and does not provide for flow equalization.

A summary of operating data for Stage 1 is shown in Table 4. The data indicates high, low, and average values. Analyses are based on 24-hour composite samples. Values shown under any column heading do not necessarily occur on the same day.

At the close of Stage 1, the following preliminary conclusions could be drawn about the two waste treatment methods:

1. The Bio-Disc could not treat 133,000 gpd (25 percent of the design plant flow) and achieve 90 percent BOD_5 removal.
2. With adequate equalizing storage prior to treatment, the wide variations in wastewater pH and temperature were minimized.
3. More satisfactory treatment was achieved in the Bio-Disc at lower flow rates provided.
4. A long detention period in the Equalization Basin produced a septic influent for subsequent treatment processes.
5. The activated sludge process generally removed 90 percent of the BOD_5 at an average flow of 92,000 gpd (17 percent of the total plant design flow), with varied MLVSS levels.

TABLE 4

DATA SUMMARY

STAGE 1

	High	Low	Average
Raw Waste			
BOD_5, mg/l	1,470	165	589
COD, mg/l	81,900	196	2,336
Suspended Solids, mg/l	1,040	4	151
Activated Sludge System (Line 3)			
Flow, mgd	0.183	0.011	0.092
MLVSS, mg/l	5,384	484	2,470
F/M, lb BOD_5/lb MLVSS	0.339	0.005	0.101
Loading, lb BOD_5/1,000 cu ft/day	5.78	0.17	1.95
Aeration Detention, hrs	32.0	532.4	63.7
Clarifier Overflow, gal/sq ft/day	418.	25.	210.
Sludge Volume Index	409	56	169
Return Solids Concentration, mg/l	12,100	3,090	6,406
Effluent BOD_5, mg/l	62	9	29
BOD_5 Removal Efficiency, %	99.6	77.6	93.9
Effluent COD, mg/l	412	6	53
Effluent Suspended Solids, mg/l	92	0	28
Bio-Disc System (Line 4)			
Flow, mgd	0.175	0.005	0.057
Biological Loading, lb BOD_5/ 1,000 sq ft/day	35.0	0.5	7.9
Hydraulic Loading, gal/sq ft/day	3.89	0.11	1.27
Equalization Time, hrs	--	--	--
Clarifier Overflow, gal/sq ft/day	764	22	249
Effluent BOD_5, mg/l	1,160	35	251
BOD_5 Removal Efficiency, %	92.6	<0	70.1
Effluent COD, mg/l	1,319	71	385
Effluent Suspended Solids, mg/l	244	0	55

6. The activated sludge process was not noticeably sensitive to variations in influent waste characteristics such as pH and temperature. This indicated that equalization of waste entering this process was of questionable benefit. This was not unexpected in view of the sizeable inherent equalization capacity of the aeration basin.

Stage 2 (February 7 to February 20, 1972 - 2 weeks)

Originally it had been planned to operate the Bio-Disc and activated sludge processes at flows of 133,000 gpd each during this stage. However, Stage 1 experience indicated that a lower flow should be applied to the Bio-Disc. The revised scheduled lower flow was 60,000 gpd.

Scheduled MLSS concentration in activated sludge process was 1,250 mg/l. Although the stage was scheduled for three weeks of operation, the activated sludge bio-mass grew so rapidly at the average waste flow of 135,000 gpd that MLSS concentrations of 1,250 mg/l could not be maintained without excessive waste of sludge. BOD_5 removals varied from 92.1 to 98.9 percent and averaged 96.1 percent.

The Bio-Disc, during Stage 2, received wastewater flows varying from 43,000 to 74,000 gpd, and averaged 63,000 gpd. BOD_5 removals ranged from 68.5 to 78.8 percent, and averaged 75.1 percent. The contents of the Equalization Basin continued to be septic.

A summary of operating data for Stage 2 is shown in Table 5 and conclusions drawn from Stage 2 operations are as follows:

1. An average BOD_5 removal of 96.1 percent in the activated sludge process at a MLSS concentration of 1,250 mg/l indicated that better than design performance could be achieved at this relatively low MLSS concentration.

TABLE 5
DATA SUMMARY
STAGE 2

	High	Low	Average
Raw Waste			
BOD_5, mg/l	1,080	605	775
COD, mg/l	1,861	641	1,168
Suspended Solids, mg/l	694	14	139
Activated Sludge System (Line 3)			
Flow, mgd	0.162	0.072	0.135
MLVSS, mg/l	1,920	952	1,471
F/M, lb BOD_5/lb MLVSS	0.613	0.177	0.350
Loading, lb BOD_5/1,000 cu ft/day	4.88	2.09	3.73
Aeration Detention, hrs	36.1	81.3	43.4
Clarifier Overflow, gal/sq ft/day	370.	165	309
Sludge Volume Index	134	65	91
Return Solids Concentration, mg/l	6,430	3,030	4,795
Effluent BOD_5, mg/l	85	10	38
BOD_5 Removal Efficiency, %	92.1	98.9	96.1
Effluent COD, mg/l	191	36	81.
Effluent Suspended Solids, mg/l	130	12	29
Bio-Disc System (Line 4)			
Flow, mgd	0.074	0.043	0.063
Biological Loading, lb BOD_5/ 1,000 sq ft/day	14.6	5.7	9.5
Hydraulic Loading, gal/sq ft/day	1.64	0.96	1.40
Equalization Time, hrs	5.5	5.2	5.4
Clarifier Overflow, gal/sq ft/day	323	188	275
Effluent BOD_5, mg/l	277	170	216
BOD_5 Removal Efficiency, %	78.8	68.5	75.1
Effluent COD, mg/l	368	77	282
Effluent Suspended Solids, mg/l	100	0	33

2. The contents of the Equalization Basin continued to be septic even with a part of the flow diverted to the activated sludge process to reduce detention time.
3. BOD_5 removal averaging 75 percent at the hydraulic rate of 63,000 gpd through the Bio-Disc was not satisfactory. This was undoubtedly due, in part, to the septic condition of waste entering the Bio-Disc.
4. The BOD_5 content of the incoming raw waste continued to vary significantly.

Stage 3 (February 21 to February 27, 1972 - 1 week)

Results of Stage 3 operations are shown in Table 6. Flows to the activated sludge process averaged 156,000 gpd which is higher than the scheduled flow of 133,000 gpd. The target MLSS level was 2,500 mg/l. Actual MLSS levels varied from 1,232 to 3,284 mg/l and averaged 2,500 mg/l. BOD_5 removals averaged 92.8 percent.

The Bio-Disc operated at an average flow of 69,000 gpd. Based on only one sample, BOD_5 removed was only 40 percent. This reduced performance compared to Stage 2 could be attributed to a flow increase of approximately 15 percent and a lower influent BOD_5 concentration. It was, therefore, decided to reduce flow to the Bio-Disc and initiate Stage 3A.

Stage 3A (February 28 to March 12, 1972 - 2 weeks)

For the activated sludge process, operating conditions were at essentially the same levels as Stage 3. Flows averaged 123,000 gpd, and MLSS levels varied from 1,650 to 2,942 mg/l and averaged 2,198 mg/l. BOD_5 removal averaged 97.9 percent. F/MLVSS levels for Stages 3 and 3A averaged 0.22.

For the Bio-Disc, average flows were reduced to 45,000 gpd (8.5 percent of plant design flow). The effluent from the Equalization Basin continued to have septic characteristics pending installation of aeration equipment.

TABLE 6

DATA SUMMARY

STAGE 3

	High	Low	Average
Raw Waste			
BOD_5, mg/l	620	290	455
COD, mg/l	710	370	540
Suspended Solids, mg/l	482	44	263
Activated Sludge System (Line 3)			
Flow, mgd	0.175	0.100	0.156
MLVSS, mg/l	2,922	1,072	2,187
F/M, lb BOD_5/lb MLVSS	0.394	0.092	0.243
Loading, lb BOD_5/1,000 cu ft/day	3.52	1.70	2.61
Aeration Detention, hrs	33.5	58.6	37.5
Clarifier Overflow, gal/sq ft/day	400	229	357
Sludge Volume Index	107	67	95
Return Solids Concentration, mg/l	8,960	3,430	5,774
Effluent BOD_5, mg/l	21	20	21
BOD_5 Removal Efficiency, %	92.8	92.8	92.8
Effluent COD, mg/l	94	50	71
Effluent Suspended Solids, mg/l	38	24	31
Bio-Disc System (Line 4)			
Flow, mgd	0.078	0.050	0.069
Biological Loading, lb BOD_5/ 1,000 sq ft/day	7.7	4.2	6.0
Hydraulic Loading, gal/sq ft/day	1.73	1.11	1.53
Equalization Time, hrs	7.1	4.3	4.9
Clarifier Overflow, gal/sq ft/day	341	218	301
Effluent BOD_5, mg/l	270	174	222
BOD_5 Removal Efficiency, %	40.0	40.0	40.0*
Effluent COD, mg/l	341	235	2,694
Effluent Suspended Solids, mg/l	62	16	33.6

*Only one sample.

The Bio-Disc, although receiving a septic influent, showed a decided improvement in BOD_5 removal rates. Removal rates varied from 55.7 to 94.3 percent, and averaged 92.4 percent for the final week of this stage. This was accomplished while the actual influent weight of BOD_5 increased from an average of 268 pounds per day during the week of February 21, to an average of 333 pounds per day for the week of March 6.

Operating data for Stage 3A are shown on Table 7 and conclusions drawn from Stage 3A are as follows:

1. Activated sludge process performance of 98 percent removal was excellent with a flow of 123,000 gpd and MLSS concentrations ranging from 1,650 to 2,942 mg/l. This indicated an increased BOD_5 removal efficiency over that shown in Stage 2.
2. At the lower flow rates of 45,000 gpd, the Bio-Disc performance increased dramatically to an average of 92.4 percent in the second week of this stage.

Stage 4 (March 13 to April 2, 1972 - 3 weeks)

Results of Stage 4 operations are shown in Table 8. Flow to Aeration Basin No. 3 averaged 114,000 gpd (21 percent of total plant design flow), and MLSS levels averaged 3,615 mg/l. This was an increase in MLSS of nearly 1,500 mg/l over that in Stage 3A. Maintaining this higher level was aimed at determining effect and performance. F/MLVSS ratios averaged 0.17, and BOD_5 removal rates averaged 93.7 percent. The process continued to receive about 50,000 gpd of septic effluent from the Equalization Basin, while the remainder of the flow consisted of raw waste. This division of flow was made to reduce detention time in the Equalization Basin. The system appeared to be unaffected by any sudden changes in influent pH or temperature.

TABLE 7
DATA SUMMARY
STAGE 3A

	High	Low	Average
Raw Waste			
BOD_5, mg/l	1,280	460	793
COD, mg/l	1,443	708	1,004
Suspended Solids, mg/l	472	60	182
Activated Sludge System (Line 3)			
Flow, mgd	0.147	0.069	0.123
MLVSS, mg/l	2,604	1,460	1,929
F/M, lb BOD_5/lb MLVSS	0.287	0.088	0.210
Loading, lb BOD_5/1,000 cu ft/day	4.51	1.27	3.27
Aeration Detention, hrs	39.8	84.9	47.6
Clarifier Overflow, gal/sq ft/day	336.	158.	281.
Sludge Volume Index	153	66	120
Return Solids Concentration, mg/l	12,950	3,590	5,873
Effluent BOD_5, mg/l	24	7	18
BOD_5 Removal Efficiency, %	98.9	97.2	97.9
Effluent COD, mg/l	94	49	75
Effluent Suspended Solids, mg/l	70	6	20
Bio-Disc System (Line 4)			
Flow, mgd	0.061	0.034	0.045
Biological Loading, lb BOD_5/ 1,000 sq ft/day	10.1	3.0	6.6
Hydraulic Loading, gal/sq ft/day	1.36	0.76	1.00
Equalization Time, hrs	12.1	11.6	11.9
Clarifier Overflow, gal/sq ft/day	266	148	197
Effluent BOD_5, mg/l	285	51	173
BOD_5 Removal Efficiency, %	94.3	55.7	75.4
Effluent COD, mg/l	588	168	301
Effluent Suspended Solids, mg/l	32	12	19

TABLE 8

DATA SUMMARY

STAGE 4

	High	Low	Average
Raw Waste			
BOD_5, mg/l	2,320	425	949
COD, mg/l	2,730	516	1,147
Suspended Solids, mg/l	384	0	134
Activated Sludge System (Line 3)			
Flow, mgd	0.155	0.033	0.114
MLVSS, mg/l	4,424	2,486	3,060
F/M, lb BOD_5/lb MLVSS	0.594	0.048	0.174
Loading, lb BOD_5/1,000 cu ft/day	12.30	1.68	4.17
Aeration Detention, hrs	37.8	177.5	51.4
Clarifier Overflow, gal/sq ft/day	354	75	261
Sludge Volume Index	139	99	116
Return Solids Concentration, mg/l	10,260	3,500	7,329
Effluent BOD_5, mg/l	108	18	52
BOD_5 Removal Efficiency, %	97.9	88.4	93.7
Effluent COD, mg/l	208	52	105
Effluent Suspended Solids, mg/l	94	6	50
Bio-Disc System (Line 4)			
Flow, mgd	0.065	0.025	0.049
Biological Loading, lb BOD_5/ 1,000 sq ft/day	23.2	3.8	8.8
Hydraulic Loading, gal/sq ft/day	1.44	0.56	1.09
Equalization Time, hrs	11.6	10.6	10.9
Clarifier Overflow, gal/sq ft/day	284	109	214
Effluent BOD_5, mg/l	174	99	138
BOD_5 Removal Efficiency, %	87.5	70.5	82.7
Effluent COD, mg/l	285	145	215
Effluent Suspended Solids, mg/l	58	8	26

The Bio-Disc received an average daily flow of 49,000 gallons. BOD_5 removals ranged from 70.5 to 87.5 percent and averaged 82.7 percent. Removals were lower than obtained under similar conditions with Stage 3A. The septicity of the influent waste flowing to the Bio-Disc was considered to be a contributing factor to the low BOD_5 removal rates. Therefore, work was initiated on the design and installation of an aeration system for the Equalization Basin.

Conclusions drawn from Stage 4 operations are as follows:

1. The activated sludge process provided BOD_5 removal of greater than 90 percent at all flow, MLSS, and F/MLVSS levels studied to this point. No optimum loading could yet be determined.
2. BOD_5 removal by the Bio-Disc decreased from that experienced in Stage 3A. This could be due to somewhat higher average BOD_5 concentrations and the slightly higher hydraulic loading, although septicity of the influent was also a factor.
3. Until a method for removing the septic conditions in the equalization basin could be provided, it was decided to maintain the flow to the Bio-Disc at about 45,000 gpd. A temporary aeration system was implemented by installing an air hose in the inlet well of the Bio-Disc to provide some improvement in the DO level of the Equalization Basin effluent. This was done at the suggestion of the manufacturer.

Stage 5 (April 3 to April 16, 1972 - 2 weeks)

Total plant flow during this stage averaged 292,000 gpd. Daily average flow to the activated sludge process was 103,000 gallons. MLSS levels ranged from 3,868 mg/l to 4,616 mg/l and averaged 4,294 mg/l. F/MLVSS ranged from 0.048 to 0.210. BOD_5 removals averaged 96.6 percent.

Flow to the Bio-Disc averaged 45,000 gpd. BOD_5 removals ranged from 57.2 to 81.7 percent, and averaged 74.8 percent.

The following conclusions are drawn from the results of Stage 5 operations which are summarized in Table 9:

1. It was initially anticipated that after Stage 5 operations were complete, an optimum MLSS level would be selected. Since BOD_5 removals had been excellent at all levels, no optimum could be chosen. It was decided to continue to maintain an MLSS concentration in the 3,500 to 4,500 mg/l range. Such a level would provide adequate protection for any moderate shock loading without upset, and still provide good BOD_5 removal.
2. Average BOD_5 removal by the Bio-Disc declined from that achieved in Stage 5. Average influent BOD_5 was somewhat higher during this period.
3. It was believed to be desirable to continue Bio-Disc operation with an influent of about 45,000 gpd until the Equalization Basin aeration system was installed and the septic conditions were eliminated.

Stage 6 (April 17 to May 14, 1972 - 4 weeks)

The activated sludge process operated during this stage at concentrations which varied from 2,676 to 4,756 mg/l and averaged 3,661 mg/l. It was planned to reduce flows to determine any effect on performance. Flows ranged from 27,000 to 150,000 gpd and averaged 79,000 gpd. F/MLVSS values ranged from 0.029 to 0.253, and averaged 0.083. BOD_5 removals averaged 97.6 percent.

Flows to the Bio-Disc ranged from 15,000 to 72,000 gpd, and averaged 48,000 gpd. BOD_5 removals ranged from 51.3 to 94.3 percent, and averaged 86.1 percent.

On May 11, the Equalization Basin aeration system became operable. This aeration system consists of a 120 cfm blower plus air piping and diffusers. By the end of Stage 6 (May 14) septic conditions in the basin had been substantially reduced, although no measureable DO was present in the effluent.

TABLE 9

DATA SUMMARY

STAGE 5

	High	Low	Average
Raw Waste			
BOD_5, mg/l	1,300	558	1,021
COD, mg/l	1,945	702	1,401
Suspended Solids, mg/l	1,184	32	406
Activated Sludge System (Line 3)			
Flow, mgd	0.148	0.035	0.103
MLVSS, mg/l	3,910	3,144	3,610
F/M, lb BOD_5/lb MLVSS	0.210	0.048	0.107
Loading, lb BOD_5/1,000 cu ft/day	6.60	1.56	3.23
Aeration Detention, hrs	39.6	167.3	56.9
Clarifier Overflow, gal/sq ft/day	338	80	235
Sludge Volume Index	204	90	118
Return Solids Concentration, mg/l	12,000	3,350	7,313
Effluent BOD_5, mg/l	37	27	32
BOD_5 Removal Efficiency, %	97.9	93.4	96.6
Effluent COD, mg/l	100	12	69
Effluent Suspended Solids, mg/l	104	6	43
Bio-Disc System (Line 4)			
Flow, mgd	0.060	0.018	0.045
Biological Loading, lb BOD_5/ 1,000 sq ft/day	11.8	3.4	8.1
Hydraulic Loading, gal/sq ft/day	1.33	0.40	1.00
Equalization Time, hrs	12.7	11.3	12.0
Clarifier Overflow, gal/sq ft/day	262	79	197
Effluent BOD_5, mg/l	264	210	243
BOD_5 Removal Efficiency, %	81.7	57.2	74.8
Effluent COD, mg/l	597	267	424
Effluent Suspended Solids, mg/l	98	8	34

As Stage 6 progressed, the MLSS in all three aeration basins began to exhibit poor settling characteristics, as determined by the Settled Volume Test. During the week of April 17, tests using a 1,000 ml sample and 30-minute settling period, indicated sludge levels from all three basins were in the range of 500 to 800 ml. These remained at this level through April 27. On April 28, the 30-minute levels rose to 980 ml for samples from Aeration Basin Nos. 1 and 2. The levels for Aeration Basin No. 3 also rose into the 800 to 950 ml range during the week of May 1. Since that time, with the exception of occasional periods of a few days of lower readings, 30-minute settling values for mixed liquor from all basins have been greater than 700 ml. These high 30-minute settling values explain the relatively low suspended solids content of the waste sludge. This factor has caused waste sludge quantities to be two to three times that originally estimated. Addition of polymers to promote settling has been only slightly successful.

Results of Stage 6 operations are summarized in Table 10. Conclusions drawn from this stage are as follows:

1. The activated sludge process continued to provide acceptable treatment even though a poor settling sludge was produced.
2. BOD_5 removal provided by the Bio-Disc, although improved over previous stages, was still not consistently in the 90 percent range.

Stage 7 (May 15 to June 18, 1972 - 5 weeks)

It was suggested by the project officer that consideration should be given to reducing flow through aeration basin and again supplying both the Bio-Disc and the activated sludge processes with the same quality of raw waste. Therefore, flows to both were routed through the Equalization Basin. The scheduled flow to each process was 45,000 gpd. The total flow of 90,000 gpd would yield an average detention period of approximately 12 hours in the Equalization Basin. Equipment for aeration of the Equalization Basin was in operation.

TABLE 10

DATA SUMMARY

STAGE 6

	High	Low	Average
Raw Waste			
BOD_5, mg/l	1,390	355	747
COD, mg/l	2,047	444	1,032
Suspended Solids, mg/l	900	16	344
Activated Sludge System (Line 3)			
Flow, mgd	0.150	0.027	0.079
MLVSS, mg/l	4,072	2,258	3,105
F/M, lb BOD_5/lb MLVSS	0.253	0.029	0.083
Loading, lb BOD_5/1,000 cu ft/day	4.75	0.88	1.99
Aeration Detention, hrs	39.0	216.9	74.1
Clarifier Overflow, gal/sq ft/day	343	62	181
Sludge Volume Index	300	95	198
Return Solids Concentration, mg/l	11,300	4,040	6,346
Effluent BOD_5, mg/l	42	7	20
BOD_5 Removal Efficiency, %	98.8	95.6	97.6
Effluent COD, mg/l	95	31	62
Effluent Suspended Solids, mg/l	78	2	28
Bio-Disc System (Line 4)			
Flow, mgd	0.072	0.015	0.048
Biological Loading, lb BOD_5/ 1,000 sq ft/day	15.5	2.1	6.6
Hydraulic Loading, gal/sq ft/day	1.60	0.33	1.07
Equalization Time, hrs	17.7	8.7	11.9
Clarifier Overflow, gal/sq ft/day	314	66	210
Effluent BOD_5, mg/l	326	44	108
BOD_5 Removal Efficiency, %	94.3	51.3	86.1
Effluent COD, mg/l	529	67	196
Effluent Suspended Solids, mg/l	84	4	38

Results of Stage 7 operations are summarized in Table 11. Flows to Aeration Basin No. 3 ranged from 33,000 to 63,000 gpd and averaged 50,000 gpd. MLSS concentrations varied from 2,392 to 5,484 mg/l and averaged 3,958 mg/l. F/MLVSS ratios were low, ranging from 0.009 to 0.127 and averaging 0.062. BOD_5 removal rates averaged 95.0 percent.

The Bio-Disc received an average of 45,000 gpd (8.5 percent of total plant design flow); total daily flows ranged from 10,000 to 59,000 gpd. Average BOD_5 removal rates varied from 76.0 to 96.9 percent and averaged 91.6 percent. These removals were achieved on an average daily BOD_5 load which, on a weight basis, was comaprable to the loads in previous stages.

Conclusions drawn from this stage of operation include:

1. At comparable hydraulic loadings of approximately 50,000 gpd, and treating the same influent waste, both processes provided average BOD_5 removal of greater than 90 percent.
2. Based upon results of previous stages, the activated sludge process was loaded at a rate well below demonstrated capacity.
3. The Bio-Disc appeared to be operating near its capacity to treat this type of wastewater based on BOD_5 removed.

Stage 8 (June 19 to July 16, 1972 - 4 weeks)

During this stage all flow to both processes continued to be routed through the Equalization Basin.

Results of operations are summarized in Table 12. This stage ended on July 16, when the distillery began an annual shutdown for vacations and maintenance. During this four-week period, the activated sludge process received an average of 78,000 gpd. MLSS concentrations varied from 2,746 to 5,986 mg/l and averaged 4,208 mg/l. F/MLVSS ratios varied from 0.045 to 1.33 and averaged 0.223. The extremely high upper value occurred on July 12, when a BOD_5 shock load of more than 31,000 pounds entered the

TABLE 11

DATA SUMMARY

STAGE 7

	High	Low	Average
Raw Waste			
BOD_5, mg/l	1,800	121	1,004
COD, mg/l	2,665	258	1,325
Suspended Solids, mg/l	1,738	42	462
Activated Sludge System (Line 3)			
Flow, mgd	0.063	0.033	0.050
MLVSS, mg/l	4,606	1,048	3,350
F/M, lb BOD_5/lb MLVSS	0.127	0.009	0.062
Loading, lb BOD_5/1,000 cu ft/day	3.44	0.22	1.70
Aeration Detention, hrs	93.0	177.5	117.1
Clarifier Overflow, gal/sq ft/day	144	75	114
Sludge Volume Index	257	36	219
Return Solids Concentration, mg/l	9,680	1,910	5,482
Effluent BOD_5, mg/l	129	7	40
BOD_5 Removal Efficiency, %	98.9	82.4	95.0
Effluent COD, mg/l	240	26	85
Effluent Suspended Solids, mg/l	176	6	51
Bio-Disc System (Line 4)			
Flow, mgd	0.059	0.010	0.045
Biological Loading, lb BOD_5/ 1,000 sq ft/day	16.0	0.9	8.4
Hydraulic Loading, gal/sq ft/day	1.31	0.22	1.00
Equalization Time, hrs	12.4	10.4	11.3
Clarifier Overflow, gal/sq ft/day	258	44	197
Effluent BOD_5, mg/l	143	23	67
BOD_5 Removal Efficiency, %	96.9	76.0	91.6
Effluent COD, mg/l	493	45	135
Effluent Suspended Solids, mg/l	130	6	37

TABLE 12
DATA SUMMARY
STAGE 8

	High	Low	Average
Raw Waste			
BOD_5, mg/l	9,680	690	1,992
COD, mg/l	9,635	990	2,723
Suspended Solids, mg/l	2,264	244	804
Activated Sludge System (Line 3)			
Flow, mgd	0.092	0.033	0.078
MLVSS, mg/l	5,986	2,278	3,649
F/M, lb BOD_5/lb MLVSS	1.33	0.045	0.223
Loading, lb BOD_5/1,000 cu ft/day	28.81	1.21	5.49
Aeration Detention, hrs	63.7	177.5	75.1
Clarifier Overflow, gal/sq ft/day	210	75	178
Sludge Volume Index	180	63	114
Return Solids Concentration, mg/l	10,630	1,700	6,361
Effluent BOD_5, mg/l	39	20	27
BOD_5 Removal Efficiency, %	99.0	97.2	97.9
Effluent COD, mg/l	474	35	113
Effluent Suspended Solids, mg/l	178	6	43
Bio-Disc System (Line 4)			
Flow, mgd	0.086	0.027	0.071
Biological Loading, lb BOD_5/ 1,000 sq ft/day	135.0	5.3	27.3
Hydraulic Loading, gal/sq ft/day	1.91	0.60	1.58
Equalization Time, hrs	8.3	6.5	7.2
Clarifier Overflow, gal/sq ft/day	376	118	310
Effluent BOD_5, mg/l	840	53	269
BOD_5 Removal Efficiency, %	95.6	49.1	80.8
Effluent COD, mg/l	1,092	63	411
Effluent Suspended Solids, mg/l	188	2	68

treatment plant. The high loading was caused by a major spill of alcohol in the plant. The activated sludge process was able to treat the resulting one day load of over 7,000 pounds of BOD_5 with no noticeable upset to the system.

COD loading was essentially the same as BOD_5. This is not unexpected since the added waste was ethanol. Data on BOD_5 and COD removal for July 12, the previous day, and the two following days are as follows:

	July 11	July 12	July 13	July 14
BOD_5				
Influent, lb	820	7,030	990	2,600
Effluent, lb	15	--	23.4	--
Removal, %	98.2	--	97.7	--
COD				
Influent, lb	1,050	7,000	1,830	3,630
Effluent, lb	26.3	93.7	39.1	66.6
Removal, %	97.5	98.7	97.9	99.2

The major effect on effluent quality should be experienced in the two days following, although some effect would be continued for an additional period. At a flow of 78,000 gpd, the aeration basin has a detention time of slightly over three days. Other parallel basins with shorter detention periods did not perform equally well although sufficient test data is not available to document this. BOD_5 removal rates for this stage averaged 97.9 percent.

The Bio-Disc received an average flow of 71,000 gpd. BOD_5 removal rates varied from 49.1 to 95.6 percent and averaged 80.8 percent. The BOD_5 removal dropped to 49.1 percent on July 13, the day following the shock load.

During Stage 8, both treatment systems were receiving an average of more than three times the weight of BOD_5 received in Stage 7. The activated sludge process continued to provide excellent removal. The lower removal efficiency of the Bio-Disc indicated that a lower BOD_5 or hydraulic loading, or both, would be necessary to achieve 90 percent BOD_5 removal consistently.

Based on BOD_5 removal performance, it was concluded that the activated sludge process should receive hydraulic loads of progressively greater magnitude following the annual distillery shutdown period. The activated sludge process exhibited no recognizable sensitivity to sudden changes in influent pH and temperature. Therefore, it was decided that in subsequent stages only the Bio-Disc influent would flow through the Equalization Basin. Flow to the Bio-Disc process for Stage 9 would be again increased to about 25 percent of total plant design flow (133,000 gpd). This would determine what affect aeration of Equalization Basin would have on performance at higher flows. Subsequent loads would be determined on the basis of the unit's response.

Stage 9 (September 11 to October 1, 1972 - 3 weeks)

In late August plant production was resumed and Stage 9 of waste treatment plant testing was resumed on September 11. During this period the activated sludge process received an average flow of 118,000 gpd. MLSS concentrations varied from 2,936 to 5,254 mg/l and averaged 4,237 mg/l. F/MLVSS ratios ranged from 0.079 to 0.257 and averaged 0.132. BOD_5 removals averaged 97.6 percent.

The Bio-Disc received an average flow of 114,000 gpd. Aeration of the Equalization Basin continued with this and all subsequent stages. BOD_5 removals ranged from negative values (effluent concentrations higher than influent) to 62.4 percent. Process effluent was of such poor quality that it was all routed from Clarifier No. 4 to Sludge Well No. 2 and returned to Aeration Basin Nos. 1 and 2 for more complete treatment.

The program of increasing hydraulic loads to the activated sludge process would be continued with resulting shorter aeration times and higher F/MLVSS ratios. MLSS concentrations would be kept at about 4,000 mg/l. Flow to the Bio-Disc would be reduced to 65,000 gpd.

Stage 9 operating results are summarized in Table 13.

Stage 10 (October 2 to October 29, 1972 - 4 weeks)

Scheduled flow to the activated sludge process was 185,000 gpd. This higher flow was planned to determine the effect of higher loading on process performance. Actual flow ranged from 95,000 to 196,000 gpd and averaged 170,000 gpd. MLSS varied from 3,685 to 6,935 mg/l and averaged 4,860 mg/l. BOD_5 removal varied from 94.6 to 98.6 percent with an average of 96.9 percent for the period.

Scheduled flow to the Bio-Disc was 65,000. It had been hoped that accumulation of bio-mass, aeration of the Equalization Basin contents, and minimizing pH and temperature peaks by adequate equalization time would provide improved performance at this flow. Actual flow averaged 55,000 gpd with a range of 28,000 to 132,000 gpd. Hydraulic loading varied from 0.62 to 2.93 gpd per sq ft with an average of 1.22 gpd per sq ft. BOD_5 removal averaged 83.2 percent which is somewhat higher than the 62.4 percent averaged removal achieved at the 114,000 gpd flow in Stage 9.

Performance data for Stage 10 are shown on Table 14 and conclusions drawn from Stage 10 operations are as follows:

1. BOD_5 removal with the activated sludge process continued to be in excess of 90 percent at higher flow rates.
2. Reduction in the flow to the Bio-Disc from 114,000 gpd in Stage 9 to 55,000 gpd in Stage 10 did increase removal efficiency from 62.4 to 83.2 percent.

TABLE 13

DATA SUMMARY

STAGE 9

	High	Low	Average
Raw Waste			
BOD_5, mg/l	1,640	403	936
COD, mg/l	3,031	640	1,383
Suspended Solids, mg/l	1,438	56	594
Activated Sludge System (Line 3)			
Flow, mgd	0.161	0.086	0.118
MLVSS, mg/l	4,328	2,380	3,488
F/M, lb BOD_5/lb MLVSS	0.257	0.079	0.132
Loading, lb BOD_5/1,000 cu ft/day	6.48	1.82	3.75
Aeration Detention, hrs	36.4	68.1	49.6
Clarifier Overflow, gal/sq ft/day	368	197	270
Sludge Volume Index	204	68	150
Return Solids Concentration, mg/l	7,910	3,920	5,772
Effluent BOD_5, mg/l	26	11	20
BOD_5 Removal Efficiency, %	98.7	96.5	97.6
Effluent COD, mg/l	111	18	56
Effluent Suspended Solids, mg/l	62	2	23
Bio-Disc System (Line 4)			
Flow, mgd	0.140	0.086	0.114
Biological Loading, lb BOD_5/ 1,000 sq ft/day	34.1	9.9	19.6
Hydraulic Loading, gal/sq ft/day	3.11	1.91	2.53
Equalization Time, hrs	10.2	8.4	9.4
Clarifier Overflow, gal/sq ft/day	611	376	498
Effluent BOD_5, mg/l	2,240	398	909
BOD_5 Removal Efficiency, %	62.4	<0	--
Effluent COD, mg/l	>1,876	395	925
Effluent Suspended Solids, mg/l	934	10	434

TABLE 14

DATA SUMMARY

STAGE 10

	High	Low	Average
Raw Waste			
BOD_5, mg/l	1,280	248	709
COD, mg/l	2,571	336	1,217
Suspended Solids, mg/l	1,310	30	490
Activated Sludge System (Line 3)			
Flow, mgd	0.196	0.095	0.170
MLVSS, mg/l	5,704	3,094	4,053
F/M, lb BOD_5/lb MLVSS	0.217	0.038	0.128
Loading, lb BOD_5/1,000 cu ft/day	7.07	1.48	4.10
Aeration Detention, hrs	29.9	61.6	34.4
Clarifier Overflow, gal/sq ft/day	448	217	389
Sludge Volume Index	174	62	130
Return Solids Concentration, mg/l	13,500	3,590	7,445
Effluent BOD_5, mg/l	29	9	21
BOD_5 Removal Efficiency, %	98.6	94.6	96.9
Effluent COD, mg/l	93	16	50
Effluent Suspended Solids, mg/l	42	4	17
Bio-Disc System (Line 4)			
Flow, mgd	0.132	0.028	0.055
Biological Loading, lb BOD_5/ 1,000 sq ft/day	16.8	2.6	7.2
Hydraulic Loading, gal/sq ft/day	2.93	0.62	1.22
Equalization Time, hrs	8.0	37.9	19.3
Clarifier Overflow, gal/sq ft/day	576	122	240
Effluent BOD_5, mg/l	246	16	106
BOD_5 Removal Efficiency, %	97.3	40.0	83.4
Effluent COD, mg/l	632	16	202
Effluent Suspended Solids, mg/l	518	8	181

Stage 11 (October 30 to November 26, 1972 - 4 weeks)

The flow to the activated sludge process was scheduled for an increase to 212,000 gpd. Actual flow varied from 86,000 to 222,000 gpd with an average of 195,000 gpd. It was planned to maintain MLSS at 4,000 mg/l; actual MLSS averaged 4,025 mg/l. F/MLVSS values varied from 0.037 to 0.361 with an average of 0.163. With this higher flow, average BOD_5 removal of 96.7 percent was essentially the same as the previous stage with a lower flow. However, a combination of increased flow and a change in the settling characteristics of the mixed liquor suspended solids resulted in the need to reduce overflow from the clarifier by increasing the underflow. This added underflow was directed to other treatment units.

In Stage 10, SVI ranged from 100 to 180 ml/gm. In this stage a number of higher values up to 290 ml/gm were experienced.

It was planned to again increase flow to the Bio-Disc slightly from that used in the previous stage. Scheduled flow was 72,000 gpd while actual flows varied from 27,000 to 74,000 gpd with an average of 65,000 gpd. This is equivalent to an average loading of 1.44 gpd per sq ft of Bio-Disc surface. During the week of November 13, effluent BOD_5 ranged from 140 to 335 mg/l. Effluent was returned to Aeration Basin Nos. 1 and 2. The reason for this upset was not determined. Effluent BOD_5 values were not used in computing average. BOD_5 removal averaged 78.8 percent.

Operating data for Stage 11 are summarized in Table 15. Conclusions drawn from Stage 11 operations are as follows:

1. With the higher flows to the activated sludge process, the BOD_5 removal of 96.7 percent was essentially the same as for the previous stage. However, clarifier overflow rate should be limited to 400 gpd/sq ft.
2. The higher flow to the Bio-Disc resulted in a reduction in average BOD_5 removal from 83.4 percent in Stage 10 to 78.8 percent in Stage 11. To achieve 90 percent removal flow must be limited to a much lower level.

TABLE 15
DATA SUMMARY
STAGE II

	High	Low	Average
Raw Waste			
BOD_5, mg/l	1,330	296	593
COD, mg/l	2,328	383	1,070
Suspended Solids, mg/l	1,758	54	387
Activated Sludge System (Line 3)			
Flow, mgd	0.222	0.086	0.195
MLVSS, mg/l	4,650	2,246	3,475
F/M, lb BOD_5/lb MLVSS	0.361	0.037	0.163
Loading, lb BOD_5/1,000 cu ft/day	9.28	0.91	4.18
Aeration Detention, hrs	26.4	68.1	30.0
Clarifier Overflow, gal/sq ft/day*	409	89	263
Sludge Volume Index	298	86	162
Return Solids Concentration, mg/l	8,460	4,820	6,393
Effluent BOD_5, mg/l	25	12	18
BOD_5 Removal Efficiency, %	98.6	92.7	96.7
Effluent COD, mg/l	123	8	53
Effluent Suspended Solids, mg/l	112	6	27
Bio-Disc System (Line 4)			
Flow, mgd	0.074	0.027	0.065
Biological Loading, lb BOD_5/ 1,000 sq ft/day	16.5	1.5	7.7
Hydraulic Loading, gal/sq ft/day	1.64	0.60	1.44
Equalization Time, hrs	14.3	39.3	16.3
Clarifier Overflow, gal/sq ft/day	323	118	284
Effluent BOD_5, mg/l	335	78	149
BOD_5 Removal Efficiency, %	87.4	74.3	78.7
Effluent COD, mg/l	407	37	229
Effluent Suspended Solids, mg/l	182	6	51

*Part of flow from aeration basin diverted as clarifier underflow to avoid carryover of suspended solids.

Stage 12 (December 4 to December 24, 1972 - 3 weeks)

During this final stage of study, the Bio-Disc and activated sludge processes were operated in series. There was a one week delay in starting this stage after completion of Stage 11. Flow from the Equalization Basin was directed through the Bio-Disc and then to Aeration Basin No. 3. Effluent from Aeration Basin No. 3 was proportioned between Clarifier Nos. 3 and 4 to achieve nearly equal surface overflow rates. This arrangement required some temporary piping changes.

Scheduled flow was 265,000 gpd; actual flow averaged 224,000 gpd. BOD_5 removal decreased to an average of 89.9 percent. This average removal rate, however, was influenced greatly by one low value.

System performance for this stage is best shown by a detailed tabulation of BOD_5 data. Operational data are shown in Tables 16 and 17. The conclusion drawn from Stage 12 is that series operation offered no advantage over parallel operation.

TABLE 16

BOD_5 DATA - SERIES OPERATION

Date	Flow (1,000 gpd)	Influent BOD_5 (mg/l)	Bio-Disc Effluent BOD_5-F (mg/l)	Activated Sludge Effluent BOD_5-F (mg/l)	Activated Sludge Effluent BOD_5 (mg/l)
Dec 4	225	1,055	--	--	--
5	221	4,125	493	43	146
6	204	920	--	--	--
7	279	1,485	1,385	560	605
8	146	795	--	--	--
11	252	1,195	--	--	--
12	250	1,115	270	31	67
13	261	705	--	--	--
14	243	1,035	663	17	24
15	184	1,410	--	--	--
18	263	--	--	--	--
19	242	545	--	--	17
20	143	--	--	--	--
21	262	--	--	--	14
22	182	675	--	--	--

TABLE 17
DATA SUMMARY
STAGE 12

	High	Low	Average
Raw Waste			
BOD_5, mg/l	4,125	545	1,255
COD, mg/l	6,215	722	1,837
Suspended Solids, mg/l	2,026	86	816
Activated Sludge System (Line 3)			
Flow, mgd	0.279	0.143	0.224
MLVSS, mg/l	4,212	742	2,721
F/M, lb BOD_5/lb MLVSS	NA	NA	NA
Loading, lb BOD_5/1,000 cu ft/day	--	--	--
Aeration Detention, hrs	21.0	40.5	26.2
Clarifier Overflow, gal/sq ft/day	--	--	--
Sludge Volume Index	201	92	127
Return Solids Concentration, mg/l	8,990	1,260	5,489
Effluent BOD_5, mg/l	605	14	146
BOD_5 Removal Efficiency, %	97.7	59.3	88.9
Effluent COD, mg/l	745	18	178
Effluent Suspended Solids, mg/l	464	4	101
Bio-Disc System (Line 4)			
Flow, mgd	0.279	0.143	0.224
Biological Loading, lb BOD_5/ 1,000 sq ft/day	169.0	22.0	53.0
Hydraulic Loading, gal/sq ft/day	6.20	3.18	4.98
Equalization Time, hrs	3.8	7.4	4.9
Clarifier Overflow, gal/sq ft/day	--	--	--
Effluent BOD_5, mg/l	--	--	--
BOD_5 Removal Efficiency, %	--	--	--
Effluent COD, mg/l	--	--	--
Effluent Suspended Solids, mg/l	--	--	--

WASTEWATER TREATMENT SUMMARY

The results of the research operation reported in the foregoing discussion define most aspects of the capability of the two biological processes to treat distillery wastewater. In general, the activated sludge process performed well under all loading conditions and can confidently be used for this type of waste treatment. The Bio-Disc system could not provide the desired 90 percent removal of BOD_5 at the design loading rate. Design criteria must, therefore, be adjusted based upon results obtained. A summary of performance is shown in Tables 18 and 19.

TABLE 18

SUMMARY OF AVERAGE BIO-DISC PERFORMANCE DATA

Stage	Influent BOD_5 (mg/l)	Flow (1,000 gpd)	Daily Loading BOD_5 (lb/1,000 sq ft)	Daily Loading Hydraulic (gal/sq ft)	BOD_5 Removal (%)
2	775	63	9.5	1.40	75.1
3	455	69	6.0	1.53	40.0
3A	793	45	6.6	1.00	75.4
4	949	49	8.8	1.09	82.7
5	1,021	45	8.1	1.00	74.8
6	474	48	4.2	1.07	86.1
7	1,004	45	8.4	1.00	91.6
8	1,992	71	27.3	1.58	80.8
9	936	114	19.8	2.53	--
10	704	55	7.2	1.22	83.4
11	593	65	7.7	1.44	78.7

Note: Aeration of Equalization Basin was initiated with Stage 7.

TABLE 19

SUMMARY OF AVERAGE ACTIVATED SLUDGE PERFORMANCE DATA

Stage	Influent BOD_5 (mg/l)	Flow (1,000 gpd)	MLVSS (mg/l)	F/M (lb/lb)	BOD_5 Removal (%)
2	775	135	1,471	0.350	96.1
3	455	156	2,187	0.243	92.8
3A	793	123	1,929	0.210	97.9
4	949	114	3,060	0.174	93.7
5	1,021	103	3,610	0.107	96.6
6	747	79	3,105	0.083	97.6
7	1,004	50	3,350	0.062	95.0
8	1,992	78	3,649	0.223	97.9
9	936	118	3,488	0.132	97.6
10	709	170	4,053	0.128	96.9
11	593	195	3,475	0.163	96.7

SECTION VII - ADJUSTED DESIGN CRITERIA

BASIC CRITERIA

To establish design criteria for distilling industry waste treatment, a number of basic factors must be considered:

1. Equalization to minimize the effect of the variations in pH, temperature, BOD_5 concentration, and flow.
2. Kinetics of BOD removal.
3. Oxygen requirements.
4. Settling characteristics of suspended solids in the waste leaving the biological step of the process.

The overall mechanisms involved in BOD removal are similar for both the activated sludge and Bio-Disc processes. Incoming organic materials measured in terms of BOD_5 are used by viable organisms in the biological reaction as food for normal metabolic needs and for propagation. To ensure an efficient biological growth, the substrate must have an adequate microorganism population, sufficient dissolved oxygen for respiration needs, and necessary nutrients such as nitrogen and phosphorus. Temperature and pH must be within a limited range.

The purpose of the biological reactor in the BOD reduction process is to convert the substrate material into suspended cell mass. Suspended cell mass is removed in a subsequent step by settling.

EQUALIZATION

Equalization for both the activated sludge and Bio-Disc processes is required to minimize wide variations in pH and temperature characteristic of distillery waste. At this installation some steps have been taken upstream from the waste treatment facilities to ensure that waste characteristics are such as to not exceed the capability of equalization facilities. Such steps include reduction in the use of highly alkaline cleaners, partial neutralization of demineralizer regenerants, and cooling of condensate from feed recovery operations.

Equalization can be provided for both processes upstream from the biological reactor. In the case of the activated sludge process, however, adequate equalization capacity has been shown to be inherent in the aeration basin which serves as the biological reactor for that process. The aeration basin in that process must also provide equalization capacity to meet two other conditions:

1. Hold a sufficient inventory of active cell mass to absorb the effect of short-term shock loads of BOD.
2. Contain sufficient substrate to maintain viable organisms during low flow or plant shutdown periods.

Based on periods of continuous temperature monitoring and frequent pH testing of the Bio-Disc influent data, it appears that an Equalization Basin with a detention period of about 12 hours is necessary to meet reported influent quality requirements of the Bio-Disc. These influent requirements are a maximum temperature of 90 F and a pH range of 6.0 to 9.5. It was not established during the test period that operation outside these limits was a major contributing cause of poor performance. Since organism metabolic processes continue during equalization storage, it has been found necessary to provide for aeration equipment to prevent an anaerobic environment. When such aeration was initiated with Stage 7, BOD removal appeared to increase. During the detention period some cell growth takes place reducing the filterable BOD. It has not been possible to verify this quantitatively.

The aeration basin of the activated sludge process has a detention time of 33 hours at design flow. Providing additional detention time in the Equalization Basin did not improve BOD removal. A shorter detention time than the design basis could be used under essentially all conditions. However, it is probable that BOD removal performance would decrease below 90 percent with some extreme shock loads. This is based on experience gained with the shock load which occurred on July 12, 1972, when plant BOD_5 load for that day was about 10 times the total plant design value of 3,200 pounds.

KINETICS OF BOD REMOVAL

The process of BOD removal from a waste by the activated sludge process is influenced by many rate mechanisms and substrate characteristics. Two models are used frequently for characterizing performance of the biological portion of the total process, as follows:

Model 1:

$$F_o = \frac{F_i}{K_m t + 1} \qquad \text{(McKinney Model)}$$

Model 2:

$$F_o = \frac{F_i}{KXt + 1} \qquad \text{(Eckenfelder Model)}$$

where: F_o = Effluent BOD_5 (filtered), mg/l

F_i = Influent BOD_5 (total), mg/l

K_m = Constant

K = Constant

X = Mixed liquor volatile suspended solids, mg/l.

t = Detention time, hrs (or days).

Use of BOD_5 rather than total first stage BOD (BOD_L) is based on the premise that the ratio BOD_5/BOD_L is same for influent and effluent.

The difference between the two models is that Model 1 does not directly consider the effect of MLVSS (assumed to be proportional to active cell mass) while Model 2 does. If the process were such that microorganisms are in the declining growth phase (F/M ratio is low), the use of Model 1 appears logical. However, Model 2 has been used to describe the process for many industrial applications.

For activated sludge process these models have normally been applied to aeration periods of 4 to 12 hours. However, they have also been applied to aerated lagoons where detention times are much longer and the MLVSS levels are much lower.

BOD_5 removal shown in data on kinetics is based on a filtered effluent sample. BOD_5 associated with all cell mass or organic material removed by filtering is not included. Therefore, to achieve 90 percent removal of total BOD_5 in the plant effluent would require a slightly higher BOD_5 removal of 92 to 93 percent based on kinetic data. Eliminating the low value of K_m obtained in Stage 7 on the basis of long detention time, the lowest value of K_m is 15.3 per day. Required detention time can be determined as follows:

$$\frac{F_o}{F_i} = \frac{1}{K_m t + 1}$$

with 92% Removal, $\frac{F_o}{F_i} = 0.08$

$K_m = 15.3$ (@ 9.5 C)

$$0.08 = \frac{1}{(15.3)(t) + 1}$$

$t = 0.75$ days

Therefore on a conservative basis, when hydraulic detention time is in excess of 0.75 days, kinetics will not be a limiting factor. Laboratory data and data from other stages would indicate a shorter detention time would be adequate to meet kinetic requirements.

For domestic waste, anticipated Bio-Disc performance can be determined on the basis of hydraulic loading. Percent BOD_5 removal decreases linearly with increasing flow per unit area of active biological surface. Some increase in percent removal takes place as influent BOD_5 concentration increases. This was not the case with distillery waste.

There have been some very recent indications from the equipment manufacturer that at higher influent concentrations of BOD_5, organic loading may be significant, particularly when expressed in terms of weight of BOD_5 per square foot of the first stage contactor. This is possibly due to limiting mass transfer of oxygen to the biological mass. Test data which had been previously collected were not detailed enough to determine this effect.

The Bio-Disc used in these studies contains six stages. Based on BOD_5 removal progression as a first order reaction, removal kinetics should be similar to that for a multi-stage completely mixed activated sludge system. Attempts to reduce actual performance data to a mathematical model were not successful.

OXYGEN REQUIREMENTS

Transfer of oxygen from the air to the waste under treatment must be adequate to supply respiration needs of the microorganisms and maintain an aerobic environment.

Oxygen uptake can be related to the rate of BOD_5 removal, MLVSS concentration, and the conversion of the reduced forms of nitrogen such as ammonia and protein to higher oxidized forms such as elemental nitrogen, nitrate, and nitrite.

In the case of the activated sludge process, the rate of absorbtion of oxygen by the mixed liquor can be determined by considering temperature, oxygen deficit, and transfer coefficients. However, under varying conditions of flow, waste strength, MLVSS, and temperature; the accuracy of averages is subject to some question. A similar mathematical approach is not available for the Bio-Disc.

A simpler approach is to examine the dissolved oxygen concentration of waste leaving the biological reactor. If a concentration of 1 to 2 mg is present, the oxygen supply is adequate. Lower residuals indicate a deficiency and higher levels indicate an excess.

For the activated sludge process, aeration equipment provided was generally adequate with deficiencies occurring during certain shock load conditions. A re-examination of design criteria indicates that by judgment aeration capacity should be increased about 30 percent to minimize the frequency of low residuals.

Oxygen supply for the Bio-Disc is governed by inherent characteristics of the equipment and is, therefore, not an independent variable as with the activated sludge process.

SETTLING CHARACTERISTICS OF WASTE

Even though the biological reactor is satisfactorily converting BOD of the waste to cell mass, overall treatment and effluent BOD_5 levels cannot be satisfactorily maintained without effective final settling.

The original design provided a nominal clarifier overflow rate of 400 gpd per sq ft for the activated sludge process and 580 gpd per sq ft for the Bio-Disc. These are conservatively based on Ten State Standards of 600 gpd per sq ft for activated sludge and 800 gpd per sq ft for trickling filters.

The adjusted design criteria set the overflow rate for both the activated sludge and the Bio-Disc processes at 400 gpd per sq ft. This limit is set for the activated sludge process based on experience with Stage 10, where suspended solids in the effluent averaged 17 mg/l with a maximum of 42 mg/l. In other stages with lower overflow rates, suspended solids concentrations have on some days been higher than those in Stage 10. However, this is attributed to transient loads or poor samples.

The nominal overflow rate for settling of the Bio-Disc effluent, as reported by the manufacturer, is 800 gpd per sq ft. For The American Distilling Company wastes, satisfactory suspended solids removal has been demonstrated at over 350 gpd per sq ft. In other instances, lower overflow rates have yielded effluent suspended solids in excess of 100 mg/l.

It has been assumed that individual instances of high effluent suspended solids concentration has been due to transient conditions or poor sampling. The adjusted design rate of 400 gpd per sq ft has been established by judgment.

ACTIVATED SLUDGE DESIGN CRITERIA

The following conclusions can be reached from the analyses previously presented:

1. Kinetics are not a controlling factor if detention time is greater than 0.75 days (18 hours).
2. Aeration capacity has been deficient at times based on the absence of dissolved oxygen in the mixed liquor. By judgment aeration capacity should be increased about 30 percent.
3. Overflow rate for the final clarifier should be limited to 400 gpd per sq ft.

The fourth criteria to be considered is system equalization requirements. This criteria can be evaluated only on the basis of experience. No rigorous model can be defined to recognize time related variations in waste characteristics.

Temperature of the mixed liquor during the test period was generally maintained between 50 F and 80 F. Only infrequent instances were experienced where temperature dropped below 50 F. These occurrences were normally during or after a weekend or holiday period in cold weather. The mixed liquor pH was always maintained in the range of 7.0 to 8.2. Therefore, the original design detention period has been adequate and could be reduced 25 to 30 percent without any harmful effect on temperature and pH of the mixed liquor.

On the other hand equalization capacity is also required to maintain an adequate inventory of MLVSS to handle low load periods and shock loads. An analysis of performance as a function of F/M ratio will provide a design basis recognizing both kinetics and equalization requirements.

Table 20 is an accumulation of all data collected on 24-hour composite samples illustrating the relationship between the F/MLVSS ratio and the resulting BOD_5 removal. This summary illustrates good BOD_5 removal rates at all F/M ratios up to 0.65. There is a good representation of data up to F/M of 0.30 and limited information above this level. It appears reasonable that a system can be conservatively designed for an F/M of 0.30.

TABLE 20

ACTIVATED SLUDGE PROCESS

F/MLVSS AND RESULTING BOD_5 REMOVAL RATES

BOD_5/MLVSS Range	Number of Values	BOD_5 Removal		
		Low (%)	High (%)	Average (%)
.01 - .05	7	94.3	98.6	96.8
.051 - .10	17	82.4	98.8	95.1
.101 - .15	9	92.0	98.6	97.2
.151 - .20	10	88.4	98.6	96.5
.201 - .25	9	94.3	98.9	97.3
.251 - .30	5	97.5	98.7	98.2
.301 - .35	1	99.0	99.0	99.0
.351 - .40	2	92.1	95.9	94.0
.401 - .45	0	--	--	--
.451 - .50	1	97.4	97.4	97.4
.501 - .55	0	--	--	--
.551 - .60	0	--	--	--
.601 - .65	1	98.9	98.9	98

The activated sludge process has demonstrated performance in excess of the 90 percent BOD_5 removal used as a design basis. Therefore, original criteria can be adjusted upward. The original and adjusted design basis for the plant are as follows:

	Original	Adjusted
MLVSS, mg/l	--	3,000
F/M, lb BOD_5/day/lb MLVSS	--	0.30
Aeration Basins		
Number	3	2
Volume (each), gal	244,000	252,000
Volume (total), gal	732,000	504,000
Influent BOD_5, lb/day	3,200	3,800
Influent BOD_5, mg/l	725	860
Flow, mgd	530,000	530,000
Aeration Basin Detention, hrs	33	23
Aerators, hp	120	160
Clarifier Overflow Rate, gpd/sq ft	400	400

Limited operating data would indicate that BOD_5 removal of at least 90 percent can be maintained at higher BOD_5 influent levels with F/M ratios increasing above 0.30.

BIO-DISC DESIGN CRITERIA

The Bio-Disc biological system installed at The American Distilling Company plant cannot adequately treat the wastewater loading of 120,000 gpd originally specified; design criteria must, therefore, be re-evaluated to provide a basis for applying the process to other installations and for arriving at the actual capacity of the existing installation.

There is a wider scattering of results obtained from the Bio-Disc unit than from the activated sludge process. Therefore, determination of reliable design criteria is somewhat more difficult. Shown below are the original and adjusted design ratings. The adjusted rating appears reasonable for the installation on the basis of actual operating results particularly those shown for Stage 7.

	Original	Adjusted
Flow, mgd	0.120	0.045
Average influent BOD_5, mg/l	725	860
Influent BOD_5, lb/day	800	322
Organic Loading, lb BOD_5/ 1,000 sq ft/day	17.8	7.2
Equalization Basin Detention, hrs	8.8	12
Clarifier Overflow Rate, gpd/ sq ft	580	400

The adjusted overflow rate is determined by judgment. These values represent the best estimate based upon available data. It would appear, however, that the activated sludge design criteria presented are somewhat more conservative than for the Bio-Disc system. The activated sludge process consistently achieved greater than 90 percent BOD_5 removal, even at loading rates considerably in excess of the revised design values specified. The Bio-Disc, however, did not consistently maintain BOD_5 removals in excess of 90 percent at the levels indicated in the revised design criteria.

RESPONSE TO SHOCK LOADINGS

The American Distilling Company operation is typical of many industries; wastewater loads exhibit frequent wide fluctuations. A biological wastewater treatment system must be able to accept these load variations and consistently provide an effluent which satisfies applicable discharge criteria. Two shock loads taken through the treatment facilities illustrate the response of the two systems being evaluated to extreme loading conditions.

On Monday, March 13, 1972, which was the first day of Stage 4, 3,000 pounds of BOD_5 entered the activated sludge process. This resulted in an F/MLVSS ratio of 0.6. Flow on this day was 155,000 gallons. No BOD_5 determination was made on the Monday effluent sample; however, COD removal was 94.5 percent. The Tuesday effluent sample, undoubtedly affected by the high load of the previous day, yielded a total effluent BOD_5 of 180 mg/l or 88.4 percent removal. On the same day, the load to the Bio-Disc was 1,050 pounds of BOD_5 representing a loading rate of 0.023 pounds per day per square foot. Flow for the day was 54,000 yielding a hydraulic loading of 1.2 gal/sq ft/day. However, part of the flow through the Equalization Basin was being diverted to the activated sludge process. Detention time was estimated to be about 10 hours. COD removal on March 13 was 90 percent of BOD_5; on March 14 was 83.5 percent with an effluent BOD_5 concentration of 154 mg/l.

The second major shock load occurred on Wednesday, July 12, 1972, during Stage 8 just prior to the plant shutdown period when a total of 31,100 pounds of BOD_5 was received at the treatment plant. Aeration Basin No. 3 was subjected to a loading of 7,030 pounds. This represented a F/MLVSS ratio of 1.33. Flow for the day was 87,000 gallons. COD removal for the day was 98.7 percent. Again, no BOD_5 determination was available for the actual day of the shock loading; however, on July 13 the effluent BOD_5 concentration was 39 mg/l representing a removal efficiency of 97.6 percent. The BOD_5 load of 7,030 pounds was approximately seven times the nominal design value of 1,070 pounds. Flow of 87,000 gallons per day, however, is slightly less than one-half of the nominal design value of 177,000 gallons per day.

On July 12, the Bio-Disc received a BOD_5 load of 6,140 pounds or a rate of 136 pounds per day per 1,000 square feet. Flow on this day was 76,000 gallons resulting in a hydraulic loading of 1.69 gal/sq ft/day. The effluent BOD_5 on July 13 was 840 mg/l and the corresponding BOD_5 removal was 49.1 percent.

From these data, it is apparent that the activated sludge system is capable of accepting shock organic loads and providing a reasonable degree of treatment. The Bio-Disc system is much more susceptible to performance loss as a result of the shock loads. Other examples of this are apparent from a review of the operational stage results. The activated sludge system performed well regardless of the equalization storage provided prior to treatment. The Bio-Disc unit could not provide a satisfactory effluent without equalization storage and without the addition of aeration to the equalization storage to eliminate septic wastewater conditions.

SECTION VIII - ECONOMIC COMPARISON

ORIGINAL COST OF FACILITIES

The wastewater treatment facilities for The American Distilling Company research project were constructed under general contract awarded by competitive bid. Two bids were received for the general construction portion of the contract. The rotating biological contactor was bid separately and two bids were also received for this unit.

General Construction Contract

Mobilization and General Expense	$ 33,000
Chlorination and Control Building	153,227
Grit Chamber	25,300
Sludge Bids	13,450
Concrete Headwall and Outfall	21,465
Pumps and Plumbing	23,000
Water Main	23,259
Gas Piping	2,000
Fence	3,030
Road	2,500
Electrical Work	63,208
Final Clarifiers (activated sludge)	139,271
Final Clarifier (Bio-Disc)	41,805
Equalization Basin (including aeration)	44,845
Aeration Basins	268,270
Bio-Disc Support (piling, substructure)	37,222
Subtotal	$894,852

Bio-Disc

Bio-Disc including installation, auxiliaries housing superstructure, an aeration equipment for Equalization Basin	$ 94,950

Cooling Tower

Cooling tower including auxiliaries and installation	$ 11,314

Engineering

Design of facilities and resident supervision	$ 106,267
Total Construction Cost	$1,107,383

The above does not include general overhead expense and special process consultation expense.

ADJUSTED COST OF FACILITIES

In order to make a meaningful cost comparison between the activated sludge and Bio-Disc processes, facilities of equal capacity must be used. Therefore, based on the performance obtained, the size of component unit operations, and unit processes have been adjusted. An activated sludge and a Bio-Disc treatment plant each with a nominal design capacity of 530,000 gallons with 90 percent BOD_5 removal are compared.

For the activated sludge process, the capital cost has been determined by removing from the original plant cost all components associated with the Bio-Disc such as:

Cooling Tower
Final Clarifier No. 4 (Bio-Disc)
Equalization Basin
Bio-Disc Support
Bio-Disc and Auxiliaries

Also, one aeration basin has been deleted and aerator capacity has been increased from 120 to 160 horsepower. The number of final clarifiers has been reduced from three to two, but overflow rate has been maintained at 400 gpd per sq ft by increasing individual clarifier size. These changes are based on adjustments dictated by actual performance attained.

Costs are at the levels in effect at the time of bidding in October, 1970.

The facility costs are as follows:

Mobilization and General Expense	$ 33,000
Chlorination and Control Building	150,000
Grit Chamber	25,300
Aeration Basins	208,000
Final Clarifiers	115,000
Sludge Beds	13,500
Headwall and Outfall	21,500
Pumps and Plumbing	23,000
Water Main	23,300
Gas Piping	2,000
Fence	2,900
Road	2,500
Electrical Work	60,000
Total	$680,000

For the Bio-Disc process, the adjusted plant size is much larger than test facilities. Therefore, a different configuration is indicated. First, the flat discs of the Bio-Disc used in the test facility installation are replaced in current equipment design by an improved design with an extended surface configuration permitting more active biological surface per unit of floor area. Therefore, the generic term rotating biological contactor (RBC) is used hereinafter to describe this type of equipment. Second, the larger installation size dictates use of an assembly of individual shafts as opposed to the completely integrated unit used in the test facility.

The arrangement selected includes one Equalization Basin sized for a 12-hour detention period and equipped with two 10 horsepower mechanical aerators. The remainder of the treatment process is divided into two equal size trains. Each train consists of the following:

Contactor (single stage - 100,000 sq ft)

Intermediate Clarifier (1,200 gpd per sq ft overflow rate)

Contactor (single stage - 80,000 sq ft)

Contactor (two stage - 96,000 sq ft)
Final Clarifier (400 gpd per sq ft overflow rate)

Cost of those components determined from current price information has been factored to late 1970 levels. The cost of other components has been based on actual original plant costs or adjusted based on size changes from original plant costs.

Estimated facility costs are as follows:

Mobilization and General Expense	$ 33,000
Chlorination and Control Building	145,000
Grit Chamber	25,300
Cooling Tower	11,300
Equalization Basin including Aeration	93,000
Bio-Surf Building	126,500
Bio-Surf Equipment and Auxiliaries	143,000
Final Clarifiers	115,000
Sludge Beds	13,500
Headwall and Outfall	21,500
Pumps and Plumbing	20,000
Water Main	23,300
Gas Piping	2,000
Fence	3,000
Road	2,500
Electrical Work	55,000
Total	$832,900

To determine total investment requirements, engineering and overhead costs must be added to the above contract costs. Engineering includes that for both design and resident supervision. Overhead costs are estimated at 5 percent of other costs.

	Activated Sludge	Rotating Biological Contactor
Construction Contract Cost	$680,000	$832,900
Design Engineering	55,700	65,700
Resident Engineering	35,000	35,000
Subtotal	$770,700	$933,600
Overhead	38,300	46,400
Total Construction Cost	$809,000	$980,000

Annual Costs

The annual costs for operating waste treatment facilities include the following:

Fixed Charges
Operating Labor and Testing
Administrative Costs
Maintenance
Chemicals and Supplies
Water
Electrical Energy

Fixed charges include depreciation, cost of money, taxes and insurance. Depreciation is computed on a straight line basis of 5 percent using an estimated facility life of 20 years.

The cost of money is determined on the basis that 40 percent of the investment will be equity capital and 60 percent debt capital. The required gross return on equity is assumed to be 22 percent with half of this attributed to taxes, yielding a net return of 11 percent. Debt capital interest rate is computed at 8 percent. The cost of money based on a combination of equity and debt capital cost is 13.6 percent. If the amortization period were assumed equal to the estimated useful life, the capital recovery factor is equal to the sum of depreciation plus average cost of money. This is 14.3 percent of the investment.

Taxes and insurance are computed at 1.5 percent of investment.

A summary of fixed charges is as follows:

	%
Depreciation	5.0
Average Cost of Money	9.3
Taxes and Insurance	1.5
Total	15.8

Activated Sludge Process

$809,000 @ 15.8% = $127,800 per year

Rotating Biological Contactor

$980,000 @ 15.8% = $154,800 per year

During the testing period two men performed all plant operating and sample testing duties. Cost including 20 percent fringe benefits was equal to $26,400 annually. It is estimated that with normal testing and operating practices this can be reduced about 25 percent to $20,000 annually for either process.

General administrative costs are those associated with time spent by policy making personnel of the distillery in connection with waste treatment plant personnel and technical operation. Although there is no rigorous basis to determine this effort, it is a real factor and is estimated at 10 percent of operating labor or $2,000 annually.

Maintenance was performed by regular distillery staff and averaged $1,440 per month or $17,300 annually. This is slightly less than 2 percent of facility investment. For projecting costs of activated sludge and rotating biological contactor facilities, maintenance is computed at 2 percent of investment.

Activated Sludge

$809,000 @ 2% = $16,200 per year

Rotating Biological Contactor

$980,000 @ 2% = $19,600 per year

The cost of chemicals and supplies averaged $300 per month during the test period. Most of these costs are associated with chemical requirements including anhydrous ammonia, triple superphosphate and chlorine. It is estimated that such costs with either the activated sludge or rotating biological contactor processes would be essentially the same. Therefore, an annual cost of $3,600 is used.

Water costs for waste treatment facility have averaged about $33 per month during the test period. Therefore, an annual cost of $400 is used for either type of facility.

Electrical requirements have been computed as follows using a unit cost of $0.01785 per kilowatt hour:

	Average Running Horsepower	Cost
Activated Sludge		
Aerators	120	$16,000
Sludge Pumps	3	400
Other	--	2,500
		$18,900
Rotating Biological Contactor		
Equalization Basin	20	2,670
Rotating Biological Contactor Drives	28	3,730
Other	--	2,500
		$ 8,900

A summary of annual costs are as follows:

	Activated Sludge	Rotating Biological Contactor
Fixed Charges	$127,800	$154,800
Operating, Labor, and Testing	20,000	20,000
Administrative Costs	2,000	2,000
Maintenance	16,200	19,600
Chemicals and Supplies	3,600	3,600
Water	400	400
Electrical Energy	18,900	8,900
	$188,900	$209,300

Both investment and annual costs are lower with the activated sludge process.

If integral plastic covers were provided for the rotating biological contactors as a means of housing rather than a building, the investment cost could be reduced $40,000 to $45,000. Annual costs would be reduced $7,000 to $8,000. The decision to take advantage of such savings would be contingent upon individual circumstances.

APPENDIX A
GLOSSARY

ACTIVATED SLUDGE PROCESS - An aerobic stabilization process for biodegradable wastes accomplished by aerating a mixture of raw waste and activated sludge to convert waste constituents to cell mass with subsequent removal of suspended matter by settling. Activated sludge consists of agglomerated biological mass containing microorganisms which utilize the waste constituents as food for growth and propagation. A part of the activated sludge in the clarifier is recirculated to the aeration basin to maintain the required organism population. Excess sludge is wasted.

BIO-DISC - A name for a rotating biological contactor consisting of a series of discs continuously rotating partially submerged in the waste stream. A biological mass forms on the discs. Disc rotation alternately exposes this mass to waste and to the air thereby providing for an aerobic stabilization of waste constituents. Suspended biological mass transferred to the waste stream is removed by settling.

BIOCHEMICAL OXYGEN DEMAND (BOD) - A measure of the oxygen necessary to satisfy needs of aerobic decomposition of degradable waste constituents. This parameter is determined by measuring oxygen depletion of sample mixed with aerated water after an incubation period at 20 C. Standard incubation period is five days and the value so determined is designated as BOD_5.

BIOCHEMICAL OXYGEN DEMAND - Filtered (BOD-F) - A BOD test performed on a filtered sample. This approximates the biochemical oxygen demand of soluble and colloidal constituents present.

CHEMICAL OXYGEN DEMAND (COD) - A measure of oxygen required to approach complete oxidation of waste constituents which are degradable by oxidation. This test is performed by measuring remaining oxidation capacity of an inorganic oxidizing solution continuously contacted with the sample for a defined period and at a defined temperature.

ENDOGENOUS RESPIRATION - The decomposition of dead cell mass by living microorganisms.

FOOD TO MICROORGANISM RATIO (F/M) - The ratio of the weight of BOD_5 entering a biological aeration system per day to the weight of mixed liquor volatile suspended solids (MLVSS) in the aeration system.

LOADING - Various criteria used to denote unit load on treatment unit operations or processes. Typical loading parameters are as follows:

Clarifiers:	Detention time, hrs
	Overflow rate, gpd/sq ft
	Solids load, lb/day/sq ft
Bio-Disc:	Hydraulic, gpd/sq ft
	BOD, lb/day/sq ft
Aeration Basin:	BOD, lb/1,000 cu ft
	Detention time, hrs
	F/M, lb BOD_5/day/lb MLVSS

MIXED LIQUOR SUSPENDED SOLIDS (MLSS) - The suspended solids content of mixed liquor in an activated sludge aeration basin. Testing is performed by filtering a sample followed by drying of residue at 103 C. Dried weight of residue is related to volume of sample with concentration expressed as mg/l.

MIXED LIQUOR VOLATILE SUSPENDED SOLIDS (MLVSS) - The volatile portion of the MLSS. Test is performed by measuring loss in weight of MLSS sample residue after ignition at 550 C. Weight after ignition is related to sample size and concentration is expressed as mg/l.

NUTRIENTS - Various elements such as nitrogen phosphorus, and potassium needed for microorganism metabolism. Deficiencies of nutrients in waste are met by addition of ammonia - NH_3 for nitrogen and triple superphosphate - $Ca\ (H_2PO_4)_2$ for phosphorus.

pH - A measure of the intensity of acid or alkaline condition of the solution. The logarithm of the reciprocal of the hydrogen ion concentration.

RAW WASTE - Waste entering the treatment facility.

RETURNED SLUDGE - Sludge removed from the clarifier and returned to the aeration basin to maintain the desired F/M ratio of the mixed liquor.

SLUDGE VOLUME INDEX - A measure of sludge settleability. The volume occupied by one gram of sludge after a 30 minute settling period.

SUSPENDED SOLIDS - Solids retained by filtering a sample of waste stream. Retained material dried at 103 C prior to weighing.

VOLATILE SUSPENDED SOLIDS - Volatile portion of suspended solids. Test performed by measuring loss of weight of suspended solids after ignition at 550 C.

WASTE SLUDGE - Sludge removed from clarifier and pumped to sludge lagoons. The quantity is equal to sludge produced less that necessary for return to aeration basin to maintain required MLSS level.

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